Forest Clearance, Wood Resource Use and the Spread of Farming in Southern Chile (400-1882 CE)

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Thesis submitted in fulfilment of the Degree of Doctor of Philosophy, Institute of Archaeology, University College London

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Abstract

Despite of the long occupation history and archaeological evidence of the temperate forest of Southern Chile (36°S - 42°S), it is commonly assumed that major landscape and forest transformation occurred only after the European colonization (1550 CE). While environmental history and ecological data indicate that the vegetation of Southern Chile was shaped by anthropic action over centuries, there is still scarce data regarding woodland burning during the pre-Hispanic periods, and little is known about the forest landscape and its clearance for cultivation and inhabitation.

This dissertation uses an archaeobotanical approach focused on both human exploitation of the environment and changes to forest composition during the Early and Late Ceramic Periods, until the Historic Republican Period (400-1882 CE). In geographical terms, the studied sites are located in the Araucanía and Biobío regions, which corresponds to what the Spaniards called the Arauco Province. In cultural terms, the area was described as a well populated land in the early written testimonies (1550-1600 CE), and today these are the regions with the highest percentage of indigenous Mapuche people.

The wood charcoal results indicate a mosaic of woody plants around the sites that does not represent old grown forest, but rather a combination of species indicative of different stages of the native forest succession, implying human shaping of the vegetation in prehistory.

Impact Statement

The temperate forests of South America, globally known for high biodiversity, host a significant percentage of endemic woody plants. Since as early as the Pleistocene-Holocene Transition, human groups exploited forest woody species not only for food and firewood, but also for their medicinal properties, and as raw materials. Although most of the traditional forest knowledge comes mainly from the ethnographic and ethnobotany studies among indigenous Mapuche people (19th century onwards), today forest resources are still collected, traded, and consumed on broader scales than just local communities. The temperate forests of Southern Chile are relevant in ecological terms, but also, they have a cultural, social and economic value to the people of Southern Chile.

Primarily, this dissertation provides original information on the long tradition of interactions between the pre-Hispanic populations of Southern Chile and the temperate forest, and the landscape modification practices that are particularly evident since the 1000 CE. While early 20th century travellers and scholars view the indigenous slash and burn practices as ecologically damaging, this project explores how burning and day-to-day activities did not generate a deforested landscape during pre-Hispanic times but maintained a diversity of forest vegetation. Contrary to traditional environmental preservation beliefs, constant controlled burning and the opening of forest clearings helps to improve forest regeneration and improves taxa diversity. Understanding that human burning shaped what today is known as a natural forest is essential in future management policies and forest regeneration initiatives. This is especially

relevant considering the current scenario of landscape fragmentation, climate change, and global warming in which wildfires are an increasing threat for smaller forest patches and local communities.

Secondly, this dissertation is a contribution to the regional archaeology of Southern Chile, which unfortunately is underdeveloped in comparison to other areas (like Patagonia or Northen Chile). In specific terms, besides the new empirical archaeobotanical data, this dissertation contributes 20 radiocarbon dates directly on identified plant taxa, helping to improve the regional chronology and opening new possibilities for archaeometric analysis.

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Table of Contents

Chapter 1: Introduction 20

1.1 Pre-Hispanic inhabitation of the temperate forest in Southern Chile 20

1.2 Geographical and chronological context 21

1.3 Research Aims 22

1.4 Methodological and interpretative approach 23

1.5 Structure of the dissertation 24

Chapter 2: Disentangling conceptions about people, forest and fire. 25

2.1 The Pristine Myth and its implications on Southern Chile conception of virgin forests 25

2.2 Understanding the forests and fire: the human impact on the landscape 35

Chapter 3: Geographic and environmental background 40

3.1 Southern Chile geography 43

3.2 Vegetation of Southern Chile 46

3.3 Paleoclimatic records of Southern Chile 52

3.4 Fire history and vegetation in Southern Chile 56

Chapter 4: Southern Chile archaeological context 62

4.1 Southern Chile archaeological chronology 62

4.2 The spread of farming in Southern Chile 73

4.3 Archaeological data in relation to pre-Hispanic landscape modification 86

Chapter 5: Southern Chile landscape descriptions (16^{th} - 20^{th} centuries) 89

5.1 Chronicles and early descriptions of Southern Chile (1550-1604 CE) 89

5.2 The free Indian country (1604 - 1825 CE) 100

5.3 Republican Period (1825 CE- present-day) 112

Chapter 6: Wood charcoal analysis as a methodological proxy 126

6.1 Wood charcoal approaches to past vegetation and wood uses 126

6.2 Wood charcoal interpretation 130

6.3 Historical development of wood charcoal analysis in Southern Chile 133

6.4 Methodological aspects of the analysis 139

6.4.1 Archaeological sites and sampling 139

6.4.2 Taxonomic identification 142

6.4.3 Taphonomy 145

Chapter 7: Mocha Island 149

7.1 Geographical, Ecological and Archaeological Context 149

7.1.1 Pre-Hispanic archaeological evidence in Mocha Island (1450 cal. BCE to 1544 CE) 154

7.1.2 European contact and forced depopulation of the Island (1544-1687 CE) 165
7.1.3 The repopulation of Mocha Island in the 19th century onwards (1840 CE to present) 179
7.1.4 Studied archaeological sites of Mocha Island 183
7.2 The P5 site 185
7.2.1 Material provenance and stratigraphy 188
7.2.2 AMS dating results: P5 Chronology 191
7.2.3 Wood charcoal analysis results 197
7.2.4 Integration of the results with previous archaeobotanical information of the site 214
7.3 The P29-1 site 217
7.3.1 Materials and sampling 219
7.3.2 AMS dating results: P29 Chronology 222
7.3.3 Wood charcoal analysis results 227
7.3.4 Integration of the results with previous archaeobotanical information of the site and the Island 243
7.4 Mocha Island: discussion of the archaeobotanical assemblage 245
7.5 Summary of Mocha Island results and interpretation 256
Chapter 8: La Cueva de Los Catalanes 257
8.1 Geographical and Archaeological Context 257
8.1.1 The 1956 excavation 259
8.1.2 The 2016 excavation 261
8.2 Material provenience and stratigraphy 265
8.3 AMS dating results: Cueva de los Catalanes Chronology 271
8.4 Wood charcoal analysis results 277
8.4.1 U1 Cueva de los Catalanes 280
8.4.2 U2 Cueva de los Catalanes 294
8.4.3 Integration of the results with previous archaeobotanical information of the site 305
8.5 Cueva de Los Catalanes discussion of the archaeobotanical assemblage 308
8.6 Summary of Cueva de los Catalanes results and interpretations 313
Chapter 9: El Arenal-1 314
9.1 Geographical and archaeological context 314
9.2 Material provenience, stratigraphy and chronology 318
9.3 Wood charcoal analysis results 323
9.3.1 Identified taxa 328
9.3.2 Unknown taxa 333

9.3.3 Non-identifiable taxa 333
9.3.4 Alterations in the wood anatomy of the assemblage..... 334
9.3.5 Diameter measurements of the assemblage 335
9.3.6 Taphonomy of the assemblage 335
9.4 Integration of the results with previous archaeobotanical information of the site 340
9.5 El Arenal-1 discussion of the wood charcoal assemblage..... 342
9.6 Summary of results and interpretations from El Arenal-1 346
Chapter 10: Discussion, conclusions and further comments 347
10.1 Integration of the results, the wood charcoal record and the forest during the pre-Hispanic and Historical Period in Southern Chile 347
10.1.1 Particularities at site level..... 347
10.1.2 Geographical and ecological differences among the analysed sites.... 350
10.1.3 Archaeological Periods and the wood charcoal data from Southern Chile 354
10.2 Conclusions..... 362
10.3 Further comments in relation to the wood charcoal analysis in Southern Chile 368
References 374
APPENDIX A: 405
APPENDIX B: 437

Table of figures

Figure 1 : Distribution of the temperate forest of South America 42
Figure 2 : Map of Southern Chile 44
Figure 3: Vegetation macrogroups of Southern Chile 47
Figure 4 : General chronology of Southern Chile. 63
Figure 5 : Chilihueque or re-hueques from Southern Chile 80
Figure 6: Geographical location of sites with wood charcoal data 135
Figure 7 : Map of the sites considered in the analysis of this dissertation 140
Figure 8 : Wood charcoal fragment showing vitrification and radial cracks. 148
Figure 9: Chronology of Mocha Island 152
Figure 10: Mocha Island Archaeological sites 153
Figure 11: Sloane Manuscript n°61 166
Figure 12: Van Noort, 1602. 171
Figure 13: Van Noort, 1602 171
Figure 14: Bry, Johan Theodor de, and Johan Israel de Bry 1602 172
Figure 15: Plate n°4 and description from Speilbergen's Journal 173
Figure 16: Image and legend from De Bry 1620 174
Figure 17: Llamas in Mocha Island. 182
Figure 18: Test pits in the P5, P29 and P31 sites. 184
Figure 19: P5-1, Photograph by the author, January 2015 185
Figure 20: ^{14}C dates of the P5 site. 192
Figure 21: Detail of the ^{14}C dates for the Ceramic Period, P5 site. 193
Figure 22: ^{14}C dates in relation to depth in TP 05.02.03 and TP 06.01.01 196
Figure 23: Weight of flotation samples from TP 05.02.03 198
Figure 24: TP 05.02.03 charcoal categories. 199
Figure 25: TP 05.02.03 percentages of charcoal categories 200
Figure 26: TP 05.02.03 taxa richness 202
Figure 27: TP 05.02.03 sample's diversity index. 202
Figure 28: TP 05.02.03 taxa ubiquity. 203
Figure 29: TP 05.02.03 wood charcoal relative frequency 205
Figure 30: TP 05.02.03 frequency of taphonomic features. 210
Figure 31: TP 05.02.03 percentage of taphonomic features. 210
Figure 32: TP 05.02.03 detail of vitrified fragments 211
Figure 33: TP 05.02.03 fragments with radial cracks 212
Figure 34: TP 05.02.03 fragments with biological markers. 213
Figure 35: TP 29.01.02, with a detail of the soil profile in the right side. 217
Figure 36: ^{14}C dates of P29 site. 222
Figure 37: Detail of the ^{14}C dates for the Ceramic Period, P29 site 223
Figure 38: ^{14}C dates in relation to depth in TP 29.01.02. 226
Figure 39: Weight of flotation samples from TP 29.01.02 228
Figure 40: Weight of excavation samples from TP 29.01.02 228
Figure 41: TP 29.010.1 charcoal categories. 229
Figure 42: TP 29.01.02 percentages of charcoal categories 230
Figure 43: TP 29.01.02 taxa richness. 232
Figure 44: TP 29.01.02 H values per samples. 232
Figure 45: TP 29.01.02 taxa ubiquity. 233

Figure 46: TP 29.01.02 wood charcoal taxa relative frequency..... 235
Figure 47: TP 29.01.02 frequency of taphonomic features 239
Figure 48: TP 29.01.02 percentage of taphonomic features..... 240
Figure 49: TP 29.01.02 detail of vitrified fragments 241
Figure 50: TP 29.01.02 detail of fragments with radial cracks. 242
Figure 51: TP 29.01.02 detail of fragments with biological markers. 242
Figure 52: Summary of Identified Woody taxa from P5, P29 and P31. 247
Figure 53: Mocha Island diversity index and taxa richness by phases..... 248
Figure 54: Sumary of Identified Woody taxa in Mocha Island..... 249
Figure 55: Entrance view of “Cueva de los Catalanes”. 258
Figure 56: Cross section view and floor plan of Cueva de los Catalanes. 262
Figure 57: Stratigraphy of U2 and U1. 267
Figure 58: ^{14}C dates of Cueva de los Catalanes..... 272
Figure 59: ^{14}C dates in relation to depth in U1.. 275
Figure 60: ^{14}C dates in relation to depth in U2.. 276
Figure 61: Weight of flotation and excavation samples from U1 and U2. 278
Figure 62: frequency of charcoal categories in U1. 279
Figure 63: frequency of charcoal categories in U2. 279
Figure 64. relative frequency of charcoal categories from flotation column in U1. .. 281
Figure 65: taxa richness in U1, according to layer and sample. 283
Figure 66: U1 sample’s diversity index. 283
Figure 67: U1 taxa ubiquity. 284
Figure 68: U1 Relative frequency of identified taxa from flotation column. 285
Figure 69: U1 frequency of taphonomic features 289
Figure 70: relative frequency of taphonomic features in U1 290
Figure 71: U1: detail of vitrified fragments 291
Figure 72: U1 fragments with biological markers 292
Figure 73: U1 fragments with radial cracks. 292
Figure 74: Relative frequency of charcoal categories in U2 294
Figure 75: taxa richness in U2 according to layer and sample. 296
Figure 76: U2 sample’s diversity index. 296
Figure 77: U2 taxa ubiquity. 297
Figure 78: Relative frequency of identified taxa from U2. 298
Figure 79: frequency of taphonomic features in U2..... 302
Figure 80: relative frequency of taphonomic features in U2. 303
Figure 81: Frequency of taphonomic features in U2. 304
Figure 82: H (Shannon-Wienner index) and taxa richness by Periods in U2 310
Figure 83: Summary of Identified Woody taxa from Cueva de los Catalanes. 311
Figure 84: General view of El Arenal-1. 314
Figure 85: Excavation plan from 2018´s excavations..... 319
Figure 86: Stratigraphy TP7, TP9 and TP8. 320
Figure 87: ^{14}C dates of El Arenal-1..... 323
Figure 88: Weight of flotation samples from TP7 and TP8. 326
Figure 89: Weight of excavation samples from El Arenal-1. 326
Figure 90: Percentages of identification categories from flotation samples..... 327
Figure 91: Frequency of identification categories from excavation samples. 327

Figure 92: taxa richness in samples from El Arenal-1, according to layer and TP... 329
Figure 93: El Arenal-1 sample's diversity index. 330
Figure 94: El Arenal-1 taxa ubiquity. 330
Figure 95: Relative frequency of identified taxa from El Arenal-1 332
Figure 96: El Arenal-1 frequency of taphonomic features. 336
Figure 97: relative frequency of taphonomic features in El Arenal-1. 337
Figure 98: El Arenal-1, detail of vitrified fragments. 338
Figure 99: El Arenal-1 fragments with biological markers. 339
Figure 100: Summary of Identified Woody taxa from El Arenal-1. 343
Figure 101: Relative frequency of charcoal categories in El Arenal-1. 345
Figure 102: Map showing the location of archaeological sites with wood charcoal in Southern Chile. 355

Table of tables

Table 1: Forest types in the transitional zone of Southern Chile. 49
Table 2: Archaeological sites with wood charcoal data from Southern Chile 136
Table 3: Location of the sites considered in the analysis of this dissertation. 140
Table 4: Archaeological sites of Mocha Island. 155
Table 5: P5-1 stratigraphy. 190
Table 6: TP 05.03.02 identified taxa 201
Table 7: TP 05.02.03 frequency of unknown Type A and Type B 206
Table 8: TP 05.02.03 non-identifiable fragments 207
Table 9: TP 05.02.03 wood charcoal anatomical alterations 208
Table 10: P29 site's stratigraphy. 221
Table 11: TP 29.01.02 identified taxa 231
Table 12: TP 29.01.02 frequency of unknown types B and C. 236
Table 13: TP 29.01.02 detail of non-identifiable fragments. 237
Table 14: TP 29.01.01 detail of wood charcoal anatomical alterations. 238
Table 15: Comparison of main identification categories in Mocha Island. 255
Table 16: Stratigraphy of U1 and U2, Cueva de los Catalanes. 269
Table 17: U1 identified taxa. 282
Table 18: frequency of unknown types in U1. 286
Table 19: Detail of non-identifiable fragments in U1 287
Table 20: wood charcoal from U1 showing anatomical alterations. 288
Table 21: U2 identified taxa. 295
Table 22: frequency of unknown types in U2. 299
Table 23: Detail of non-identifiable fragments in U2. 300
Table 24:El Arenal-1 Stratigraphy 321
Table 25: El Arenal-1 identified taxa. 328
Table 26: frequency unidentified types in El Arenal-1. 333
Table 27: Detail of non-identifiable fragments from El Arenal-1. 334
Table 28: wood charcoal from El Arenal-1 showing anatomical alterations. 335

Chapter 1: Introduction

1.1 Pre-Hispanic inhabitation of the temperate forest in Southern Chile

The archaeological evidence from the temperate forest of Southern Chile (western slopes of the Andes, 36°S - 42°S) indicates that forest resources have been exploited since the arrival of the first hunter-gatherer groups to the region ca. 15,000 years ago. Despite the long occupation history and archaeological evidence, it is commonly assumed that major landscape and forest transformations occurred only after the European colonization (1550 CE). In the traditional archaeological discourse, the idea prevailed that small-scale agriculture or horticulture subsistence of indigenous people did not modify significantly the forest environment described, which was later regarded as pristine by the naturalists of the 18th century.

After the incorporation of archaeobotanical methodologies, the recent decades of archaeological research have provided direct evidence for the adoption of cultivated plants from the Early Ceramic Period (400-1000 CE) onwards. During the following Late Ceramic Period (1000-1550 CE), the archaeological records show a consolidation and intensification of crops, management of camelids, public architecture and landscape modification, all related to population growth. The archaeobotanical record also shows that wild edible forest resources kept being consumed along with the cultivated plants, but very little is known about the forest landscape and its clearance for cultivation and inhabitation.

This project proposes an archaeobotanical approach focused on both human exploitation of the environment and changes to forest composition. The study first explores how pre-Hispanic societies of Southern Chile interacted with forest wood resources to meet their caloric requirements and satisfy their combustion needs. The archaeological evidence is also complemented with the use of the early written records in order to obtain a historical perspective on the forests, described after the 18th century as natural environments.

1.2 Geographical and chronological context

The ecological context of this project is the temperate forests of Southern Chile, distributed between the 35°S-55°S, but the specific area of study corresponds to the territory between the Biobío River and the Reloncaví Gulf (36°S - 42°S). The studied sites are located in the Araucanía and Biobio regions, which in ecological terms, have been described as a transitional vegetation zone that includes sclerophyllous and lauriphyllous species (Luebert & Pliscoff 2006, p. 77). In chronological terms, the project considers archaeological samples that as a whole cover from the Early Ceramic Period (400-1000 CE), the Late Ceramic Period (1000-1550 CE), and the Historic Period (1550-1882 CE). In the regional archaeology, these periods represent the transition from a mobile hunter-gatherers groups to more sedentary and agricultural societies, and finally the transformations caused by the Spanish conquest.

1.3 Research Aims

Since not much is known about how pre-Hispanic societies interacted with their forest environment, the primary aim is to evaluate as a whole the available evidence in relation to the use and exploitation of forest resources and how it might have changed through time. Using wood charcoal analysis, the anthropic effect on the forest landscape will be evaluated, giving attention to geographical and ecological characteristics particular to the areas represented by the archaeological sites.

Overall, this project is focused on establishing the level of forest clearance in relation to social processes associated with the transition from hunter-gatherer to agricultural subsistence systems and subsequent changes up to the Historic Period. In more specific terms, the main research questions leading this investigation is:

Is it possible to observe changes to temperate forests composition of Southern Chile between the Early Ceramic Period and Historic times? If so, is it possible to link this transition to increased agricultural production and animal management?

What was the nature of human impact over these periods and how did this contribute to the composition of the forest as they were observed in early historical times?

1.4 Methodological and interpretative approach

Considering the low resolution of most paleoenvironmental studies in relation to archaeological and cultural time scales (Abarzúa *et al.* 2014), this study is based on datasets tied directly to archaeological evidence and chronologies. Considering that wood charcoal is the most abundant vegetal remain found in archaeological sites, anthracology or wood charcoal analysis is proposed as the principal methodological approach. The last decades of development of this discipline have demonstrated that wood charcoal analysis is viable approach to study past woodland vegetation and its transformations through time (Kabucku 2018). In particular, it provides a record of cultural practices of forest clearance, tree management and firewood exploitation (Asouti & Austin 2005, Théry-Parisot, Chabal & Chrzavzez 2010) which are directly tied to cultural chronologies and therefore can better inform on the anthropogenic role in wider environmental changes of the past. For the specific case of Southern Chile, wood charcoal analysis is an underdeveloped area of archaeobotany, but that so far has shown great potential to study the interactions between pre-Hispanic societies and the forest landscape. Combining datasets, such as seed/fruit identification or phytoliths, and wood charcoal, offers complementary evidence that integrates information on subsistence with the wider availability of vegetal resources including those used as fuel, and it provides a source for characterization of the vegetal surroundings of archaeological sites (Lehnebach *et al*. 2008).

1.5 Structure of the dissertation

This dissertation is divided into 10 chapters and two appendixes. Chapter 2 examines how the pristine myth has influenced the archaeological discourse in Southern Chile, but also preconceptions about the relationship between people, fire and forest. Chapter 3 presents an overview of the zone of study in terms of geography and ecology, including paleoclimatic information. Chapter 4 gives a synthesis of the archaeological knowledge of Southern Chile. Chapter 5 presents a revision of published historical sources used with the purpose of reconstruct the landscape of Southern Chile after the Spanish conquest. Chapter 6 contains the methodological and interpretative framework of the dissertation, focused on wood charcoal analysis, and also gives a historical context of the discipline in Southern Chile. Chapter 7, 8 and 9 are dedicated to the case studies, and each includes the geographical and archaeological context for each of the sites, as well as the archaeobotanical results. For the case of Mocha Island, Chapter 7 includes a section that reviews the specific Historical sources available for the island. Finally, Chapter 10 contains an integration of the results intended as a general discussion, to then present the conclusions and final comments.

All the supplementary information is gathered in appendix A, while appendix B contains the anatomical descriptions of the identified taxa and photos of archaeological samples.

Chapter 2: Disentangling conceptions about people, forest and fire.

2.1 The Pristine Myth and its implications on Southern Chile conception of virgin forests

After the arrival of Cristobal Columbus to the Americas (1492 CE), finding the geographical location of the Eden Garden became a possibility for some European conquerors, explorers, and historians of the epoch (Wachtel 2015). While Columbus declared to have encountered the Eden, Amerigo Vespucci stated he was in the earthly paradise or really close to it (Perelmuter-Perez 1986). The early nature descriptions of the Americas usually included references or comparisons to a terrestrial paradise, depicting unrealistic landscapes where no humans have ever set foot.

The idea of a virgin pre-Columbian landscape barely affected by humans was then popularized in contraposition to the European industrial landscape (Williams 2006). Under this conception, the native populations of the Americas were depicted as noble savages who lived in harmony with their surroundings and were unable to disturb the environment in a serious way (Pyne 1997, p. 242). The pristine myth of the Americas and the noble savage perspective supports the idea that all major landscape and forest transformation occurred only after the European colonization (Denevan 1992). Although both conceptions shared a romantic component, the idea of pre-Columbian groups incapable of altering the forest landscape in a significant way was influenced as well by evolutionism and environmental determinism of the 19th century. The noble savage was believed to represent a primal stage of humanity, before the

development of environmental management technologies or land-altering practices, and without them, the environmental determinism perceived the existence of forests as impassable barriers for human settlement (Coughlan 2015, p. 706-707). Because of the lack of iron tools, such as axes and the role they played as barter items during the Colonial Period, the pre-Columbian Americans were conceived as unable or unwilling to modify their environment or burn the forests and land.

There is no doubt that European colonisation caused a significant ecological impact in the Americas directly associated with the decline of the native human and animal population, the introduction of Old-World animal and vegetal species, and related pests and diseases (Crosby 1972, 1993). Nevertheless, a review of the historical, archaeological, and paleoenvironmental records suggests that the Americas were far from being an Eden Garden prior to 1492 (Arroyo-Kalin & Riris 2021, Dull *et al*. 2010, Koch *et al.* 2019). Crops such as maize had been in use in the Andes region at least 5000 years BP, earlier than Mesoamerica (Kistler *et al.* 2020). There is also abundant evidence of agricultural intensification in the Andes and parts of the lowland tropics including cultivation terraces, hydraulic systems, and raised field systems, such as the Lake Titicaca in the high Andes, the ridged fields of the Llanos de Moxos in Bolivia, and the raised field systems of Suriname and Guyana (Denevan 2001). In Amazonia and the temperate forest of North and South America, slash and burn were practiced not only for cultivation purposes but also to promote wild edible plant development (Arroyo-Kalin 2012). It has been estimated that after the European arrival, a median area of 55.8 million hectares of land that

were once managed by indigenous people in the Americas, were abandoned and revegetated (Koch *et al.* 2019, p. 13). Some authors have even suggested that the decline of the indigenous population in the Americas (related to warfare and the newly introduced diseases) caused a drop of the CO_2 concentrations registered by 1610 CE on Ice core records (Dull *et al*. 2010, Lewis & Maslin 2015). For the northern hemisphere of America, estimations suggest that by 1650 the native indigenous populations were reduced by about 90%, while the European population and settlements started expanding (Denevan 1992, p. 379). Most of the early testimonies describing vegetated forests and uninhabited lands were written by eyewitnesses who travelled around 1750-1850. By that time, the supposedly abandoned lands and interior regions were reforested in the absence of native burning, large-scale cultivation, and forest clearing activities.

For the specific case of the temperate forest of Southern Chile, the written testimonies by Góngora Marmolejo (recording first eyewitness accounts from European arrival until 1575), Mariño de Lobera in 1551, and Rosales in 1674 all record the existence of cultivation fields and prairies interdigitated with woodland patches (Camus 2002). Previous transdisciplinary reconstructions of Southern Chile have estimated that by 1550 CE the native forest cover was around 68.3%, while prairies and shrublands were 13.8% (Lara *et al*. 2012, p.17). These percentages correspond to about 11 million hectares of native forest while prairies and shrublands occupied 2 million hectares. This same study proposes that the territorial pattern of indigenous populations produced a land use mosaic, estimated on 890 thousand hectares (5.4 % of the territory).

This mosaic pattern consisted of different patches of prairies, shrublands, agricultural fields, and human settlements of diverse extensions. Because these areas were the result of forest clearance, they also included some forest stands.

In addition, some of the early written descriptions mention the existence of dense inhabited valleys south of the Biobío River and different estimations have been calculated over the years. Based on the chronicles and early documents, by the onset of the European colonisation some estimate a population of around 600 to 800 thousand people between the Biobío River and the Chiloé Island (36° to 41°S). For instance, in a letter written in 1593 to King Carlos V of Spain, Oñez de Loyola estimated a population of 180 thousand people just in the Imperial basin river valley (Otero 2006, p.36). More recent approaches also consider the official records of *repartos de encomiendas*. These records state how many indigenous people were assigned to each conqueror granted with an encomienda, the system in which indigenous people were forced to work in mining or agricultural work (Sauer 2015). José Bengoa estimates the population of the Araucanía region on over a million people (Bengoa 2004, p. 273). But by also considering the indigenous people who were not officially assessed by the Spaniards, the overall population could have easily reached around 1.2 million people (Bengoa 2003, p. 154-158). Although some previous estimations agree with a population of around one million people (Hidalgo 1972, p. 35), others have considered this amount optimistic or exaggerated (León 1981), proposing a population of one million people for the entire Chilean territory and not just the Araucanía region (Mellafe 1959, p. 215). At the other

extreme, Gonzáles de Nájera suggested a larger population of two million people only in the Araucanía region (1889, p. 97), but this might be an exaggeration intended to justify the military failures of the Spaniards conquerors (Bengoa 2003).

Independently of the exact number of people, the indigenous population rapidly decayed. Between 1565 and 1598, battles against the conquerors were frequent and caused the destruction of the Spanish settlements south of the Biobío River. Apart from the direct deaths of the conquest war, the new diseases brought from the old world had an early and fast effect on the indigenous population. Almost simultaneously to other territories (like Brazil and Paraguay), an explosive outbreak of smallpox was documented in Chile between 1562 and 1565 (Crosby 1993, p. 203). Later outbreaks of measles, smallpox, and typhoid fever wiped out most of the indigenous people and especially deadly were the ones reported between 1588 and 1590 (Mellafe 1959, p. 218). Although no specific estimations for Southern Chile have been calculated, by 1600 CE the total indigenous population in Chile was estimated in 500 thousand people (Mellafe 1959, p. 223).

As detailed in chapter five, the descriptions of Southern Chile's pristine forests and exuberant vegetation were written during the second half of the 19th century, and they reflected a forested landscape resulting from population decimation and abandonment of previously managed land (Camus & Solari 2008). If by 1558 around 200 thousand people were living in the plains near Osorno (40°S), by 1804 only two thousand people were left (Otero 2006, p. 60). The previous cultivation and pasture fields were abandoned for almost 300

years, while pioneer and shade-intolerant species had likely taken over the territory and restored part of the native forest. Naturalists and travellers who visited Southern Chile, like Darwin in 1839, Treuler between 1851 and 1863, Domeyko in 1845, or Phillipi in 1852, all described dense forest landscapes (Camus & Solari 2008, Otero 2006). Although they also report the existence of cultivation fields and indigenous settlements, they repeatedly referenced and described virgin forest. The Spanish terms for jungle and woods (*selva* and *monte*) were used frequently instead of the term forest (*bosque*). Although today the term *monte* commonly means in Spanish a hill or mount, in the written sources from the 16th century is mainly used to indicate a vegetal formation dominated by shrubs and trees where the transit is difficult (Villalobos 2018, p. 190). Therefore, by highlighting the wild aspect of the territory, these descriptions contributed to the idea of an uncivilized and unpopulated land, despite the decimated but still present indigenous populations.

This traditional view of Southern Chile forest as pristine or virgin environment was embedded for a long time in the natural, geographical and ecological descriptions. In 1950 a compilation of the Economic Geography of Chile (Geografía Economica Chilena, CORFO) included as a biogeographic type the Park Formation (Formación Vegetal de Parque), mostly distributed in the valleys and littoral plains between the Malleco and Cautín Rivers (Fuenzalida & Pisano 1965). This formation was characterized by a combination of prairies and forests; while an herbaceous cover dominated in open areas, forest could be found in areas with abundancy of hydric resources (like riverbanks). The most common tree species of this park formation is mentioned to be

Nothofagus obliqua (Mirb.) Oerst. and *Nothofagus dombeyi* (Mirb.) Oerst., species known as colonizers after stand-replacing fires (Armesto et al. 2009a). By not mentioning the origins of this formation, it could be easily assumed that the park landscape responded only to climatic and geographical variables masking the anthropic factor. Although as a term the Park formation is less frequent nowadays, it can still be found in reeditions of books originally published in the 1980´s (Hoffmann 2005).

Until the 1980's it was common to find papers using the pristine and virgin adjectives to refer to the undisturbed native forest of Southern Chile (Burschel *et al*. 1976, Donoso, Escobar & Urrutia 1985, Schmidt 1977). Although less frequently, is still possible to find more recent publications using "near-pristine" as a concept (Nanavati et al. 2020). Instead of pristine or virgin, the old-growth forest term is also used to describe ecosystems that have not experienced frequent and significant anthropic impact (Armesto *et al.* 2009b, Gutiérrez *et al.* 2009). In Southern Chile, these forests maintain a vertical structure where large shade-tolerant trees are dominant (over 200 years old broad-leaved evergreen species) along with emergent pioneers' species (Echeverría *et al.* 2012). The distribution of these forests is restricted today to part of the Andes Cordillera and some coastal areas. But in regards of the conceptual aspects, there seems to be no consensus among the international scientific community Several terms, such as natural, near- and semi-natural, undisturbed, virgin, pristine, and primary forest, are frequently and sometimes indistinctly used as well as ancient woodlands or old-growth forests (Burrascano 2010, Gutiérrez *et al.* 2009, Veen *et al.* 2010).

From the environmental sciences, there is an increasing recognition of the unlikeliness of any forests being completely free of human impact (Ellis *et al*. 2013). Recent publications from the environmental and ecological sciences have incorporated the idea of "anthropogenic landscapes" in relation to landscapes initially believed to be natural or pristine (Hayashida 2005). In other parts of the world, such as Amazonia, Central Africa, and Southern Thailand, the false idea of virgin or pristine forest has been discussed for the last 30 years (Gemerden, *et al.* 2003, Levis *et al.* 2012, Willis, Gillson & Brncic 2004). In Southern Chile, the publications debating the virgin forest misconception come from the environmental history area (Camus & Solari 2008, Camus 2005, Lara *et al.* 2012, Otero 2006). Since these studies mainly rely on historic sources, archaeological data is rarely considered. While some papers recognize human agency on the forests (Abarzúa 2009, González *et al.* 2020, Nanavati *et al.* 2020), or the lack of knowledge during Pre-Hispanic times (Armesto *et al.* 2010), others, usually based on out-dated archaeological literature from the 19th or early decades of the 20th century, suggest a minor disturbance (Alaniz 2019, Montalba *et al.* 2017, Moreno-Gonzalez, Giesecke & Fontana 2020), and some even assume a pristine or natural state of the forest previous to the Spanish Colonization (Peña-Cortés et al. 2020).

Until the beginning of the 1990's, the concept of a virgin pre-Columbian forest was assumed without further discussion among archaeologists in Southern Chile. Under this view, the original or primal stage of Southern Chile forest was understood as a human-free territory or with minimal anthropic influence of hunter gatherers. Because they were thought of being harmoniously integrated

to the trophic chain and incapable of causing mayor disturbance, a modified or cultural landscape was only possible after the introduction of agriculture (Ramírez & San Martín 1993). As in other parts of the continent, and because of the lack of metal tools such as axes, the forests of Southern Chile and the wet climatic conditions were conceived as an impediment to the development of pre-Hispanic agriculture. Some authors assumed that trees were mostly used as firewood (possible by the collection of dead wood), leaving most of the territory south of the 36°S covered by dense forests (Armesto, Villagrán & Donoso 1994). In accordance with these ideas, the archaeological publications of that decade assumed that pre-Hispanic Southern Chile populations had a rudimentary horticulture or incipient seasonal agriculture that relied on a small-scale slash and burn of the forest (Aldunate 1989, Dillehay 1990). These assumptions were based on ethnohistoric data without any archaeological foundation, and only after the implementation of archaeobotanical methodologies these ideas have been recently contested using direct evidence from plant remains (Campbell, Roa & Santana 2018, Dillehay 2014, Roa *et al.* 2018).

The recent decades of systematic archaeological research have introduced into the discussion novel topics in the region such as social complexity, agricultural intensification and landscape modification (Campbell & Pfeiffer 2017, Dillehay 2007). Although since the 1990's there has been important development in the archaeological knowledge of the region, forest use has been discussed in the Southern Chile archaeology mainly in terms of food availability and resources supply (Aldunate & Villagrán 1992, Gallardo & Mege

2012, Lehnebach *et al*. 2008). Between the 1990's and 2000's some archaeological projects in the region directed their focus to the temperate forest proposing an archaeological tradition of the Temperate Forest (*Tradición Arqueológica de los bosques templados* by Adán, García & Mera 2010). The main output of this proposal was the human adaptation to the environment giving importance to the biodiversity and high availability of resources in order to demystify the forest as an unsuitable territory for human occupation (Adán *et al.* 2016), but without much consideration of how human presence could have modified it.

To summarise the broad context of this research, pre-Hispanic human agency on Southern Chile forests has been underestimated for years not only by the environmental sciences but also by archaeology. Although it is usual to find papers where the increase of fire activity during the Holocene is interpreted as a signal of human presence (Abarzúa 2009, LeQuesne, Villagrán & Villa 1999, Moreno *et al.* 2001), it is less likely to find publications where this topic is developed further in order to discuss the anthropic component of the Temperate Forests of South America (González *et al*. 2020, Nanavati *et al.* 2020).

2.2 Understanding the forests and fire: the human impact on the landscape

Fire is a great modeler of the landscape especially concerning the dispersal and distribution of plant species. Once humans learnt how to control fire, the rate of fire events were augmented and expanded along with human populations implying the sub-consequential modification of the environment (Coughlan 2015, Pyne 1997). According to Williams (2006, p.13), there is no ethnographic evidence of past and contemporary indigenous or aboriginal societies deliberately extinguishing opportunistic fires in order to preserve vegetation. On the contrary, fires were allowed to burn for weeks because they maintain and promote grasses, tubers, bushes, and edible plants that in turn favour and support a greater number and density of animals. From a historic perspective, fire suppression initiatives and fire management policies are recent in the history of humanity (Wagtendonk 2007), and in Southern Chile, they were implemented only during the second half of the 20th century.

Regarding paleoenvironmental reconstructions, the real magnitude and impact of anthropogenic fire is still uncertain. Whether intentional or unintentional, the spatial effects of human-induced fires are debatable, as well as the possibility that they might overlap or override natural fire regimes. Distinguishing anthropogenic fires in relation to past environmental modification is not straight-forward, since the anthropic effects on fire regimes may not be noticeable in paleoenvironmental records given the low resolution and limitations of some research methods (Coughlan & Petty 2012). Spatial and temporal scales inherent in palaeoecological studies are much broader than those identified by

archaeology and specified in social, economic, and political process. Resulting fire activity variations, therefore, may not be distinguishable from in conventional palaeoecological proxies.

For regions where lightning is rare, like the temperate forests of New Zealand and South America, changes in fire regimes are usually attributed to human activity. Previous studies that have tried to discriminate between human and climate effects on wildfire activity in Patagonia (42°S-48°S) have concluded that it is still difficult to separate the anthropic influence from climate variability (Holz & Veblen 2011), and even though there is no causal evidence, they appear to be correlated (Mendez *et al.* 2016). The evidence from Patagonia indicates that at large scales primary climatic conditions restrict fire activity, but once favourable conditions are established for the spreading of fires, the pulses in fires respond to human ignitions (Holz *et al*. 2016).

The ethnographical and ethnohistorical record indicates that fire has been used for centuries among the indigenous population of the temperate forest of South America to modify the landscape intentionally (Otero 2006, Solari *et al.* 2007). Besides the already mentioned clearance of forest for cultivation and pasture fields, fire was used to keep travel routes clean, especially across the Andes. If the paths were not maintained, the *Chusquea* bamboo could rapidly overtake the area impeding expedited transit between both slopes of the Cordillera (Veblen *et al.* 2006). In forest of *Araucaria araucana* (Molina) K. Koch (a fire-resistant dominant tree species), the fire was used to maintain a clean understory and facilitate the collection of nuts (Nanavati *et al.* 2020). Fire was also used among the hunter-gatherer Pehuenche groups of the Andes and

Patagonian hunter-gatherers like the Aonikenk to facilitate the hunt of wild camelids (*Lama guanicoe*) and other animals (*Rea pennata*) (González et al. 2020, Martinic 1995, p.286).

Although there is consensus about the role of human ignitions in fire activity, there seems to exist less reflection concerning how the anthropic intervention of the landscape might diminish or increase “natural” fire rates (Bowman *et al.* 2011). Fire alone produces three major changes in forest composition and structure: it opens the forest, creates grasslands, and alters the species composition and age range of trees (Williams 2006, p. 26). Other activities such as wood collection, timber harvest, and forest management practices have effects on the naturally occurring fuel load of the environment. So, in the event of lightning, there is less fuel available to expand the fire. By introducing exotic species and altering the land use, land cover, and land management patterns, the averages of fuel moisture can be increased or decreased concerning “natural conditions”. Depending on that, naturally occurring fires might propagate with more difficulties or facilities. Other types of landscape modifications such as roads might also act as artificial barriers suppressing fire spread.

The historical and dendrochronology record of Southern Chile shows a dramatic increase in fire frequency after the second half of the 19th century as a result of the European colonization promoted by the Chilean State (Gayo *et al.* 2019, González *et al*. 2020, Holz & Veblen 2011, Otero 2006). Unfortunately, no regional dendrochronological records inform of the periods before the 1500 CE. Nevertheless, it seems possible that the seasonal indigenous burning of

forest patches and wood collection could have limited the dispersal of large fires. In contrast, and under the appropriate climatic conditions, the large forest cover unmanaged for centuries after the Spanish arrival could have facilitated a fire expansion after 1850.

Since the second half of the 20th century, wildfire suppression programs started incorporating the traditional native use of controlled fires to reduce extensive wildfire occurrence (Pyne 1997). More recent restoration and biodiversity initiatives and studies have highlighted the importance of incorporating traditional and indigenous management practices (Bliege Bird & Nimmo 2018). Different studies have indicated that the spots with mayor biodiversity in some areas are in close territorial relation to existent or previous human settlements, as Bliege Bird and Nimmo (2018) indicate for Australia and Neves & Heckenberger (2019) for Amazonia. The ethnographic data reports that the intentional transport and distribution of plants was common among Mapuche people. Plants that were abundant in specific areas were distributed to zones where they were less frequently found (Bragg, Hauenstein and Latsague 1986), contributing to enhancing the biodiversity of the territories. The intention is not to revive the old notion of the noble savage who lived in harmony with the environment but recognize that human populations shaped biodiversity in ways that were positive or negative (Balée 2010). According to Gayo and collaborators, for over 3000 years the pre-Hispanic populations of Southern Chile set fire to the forest, with the deliberate purpose of clearing and opening patches of native forests (Gayo *et al*. 2019, p. 16). This burning should be understood as land-management practices that also modelled the distribution

of plant species. It is clear that the decrease of native forest coverage was not steady through time, and as the historical sources indicate, part of what was cleared during pre-Hispanic times was then reforested between the 16th and 18th centuries, to be burned during the 19th and 20th centuries.

Chapter 3: Geographic and environmental background

The broad ecological setting of this project are the temperate forests of South America (figure 1). These forests are known as temperate because they are found far from the tropical regions (over the 30° of latitude in both hemispheres), and they are subject to low winter temperatures. Although the temperate forests show less plant diversity in comparison to the tropical forest, the tree species from these forests are worldwide recognized in relation to timber production (Armesto, León & Kalin 1996).

The Temperate Forest of South America is the larger remaining forest of this type in the Southern hemisphere (Armesto et al. 2009b). The geographical constrictions such as the Andes Cordillera, the Pacific Ocean, and extremely dry environments such as the Atacama Desert and Argentinians Pampas (part of the “Arid Diagonal of South America”) were responsible for the isolation of these forests (Villagrán & Hinojosa 1997). Since the late Tertiary, the temperate forest biota evolved in isolation, as evidenced by the high number of endemic species and isolated genera (Smith-Ramírez 2004). In addition, several of the isolated plant genera belong to monogeneric families, which suggest antiquity and probably high Pleistocene’s extinction rates (Villagrán & Hinojosa 1997). Today, the Temperate Forests are found as a narrow band in the southwestern margin of the continent, between the 35° S and 55°S. Most of the current temperate forest extension corresponds to the Chilean territory (between the Maule River and Tierra del Fuego), but in the Southernmost region it can also

be found in the eastern slope of the Andes, which corresponds to the Argentinian Patagonia.

In Chile the current forest dispersion is restricted to higher elevations (Andes Cordillera and Coastal range), and the species and flora associations vary with latitude. Three main types of temperate forest can be described from north to south, starting roughly south of the Maule River with the deciduous dominated forest type also known as "*bosque Maulino*". South of the Biobío River predominates the evergreen Valdivian rainforest (also known as "*bosque lluvioso valdiviano*"), and finally the subantarctic or Patagonian Forest, is found in the Chilean channels and Patagonia (Armesto *et al.* 2009b). In comparison, the Valdivian rainforest shows the highest flora richness among the evergreen temperate forests of the planet, and it has been declared a biodiversity hotspot (Smith-Ramírez 2004).

Unlike the northern hemisphere of America, the Temperate Forest of the southern hemisphere shows a dominance of angiosperms over conifers and a predominance of evergreen over deciduous species (Armesto, León & Kalin 1996). Woody plants of these forests have diverse habitus, including trees, shrubs, subshrubs, climbing shrubs, parasite shrubs, succulent shrubs, among others woody life forms (Rodriguez *et al.* 2018). Unlike tropical areas of South America, the lianas from these temperate forests are not pioneer plants and they can develop under different light conditions, even under a dense canopy (Valladares, Gianoli & Saldaña 2011).

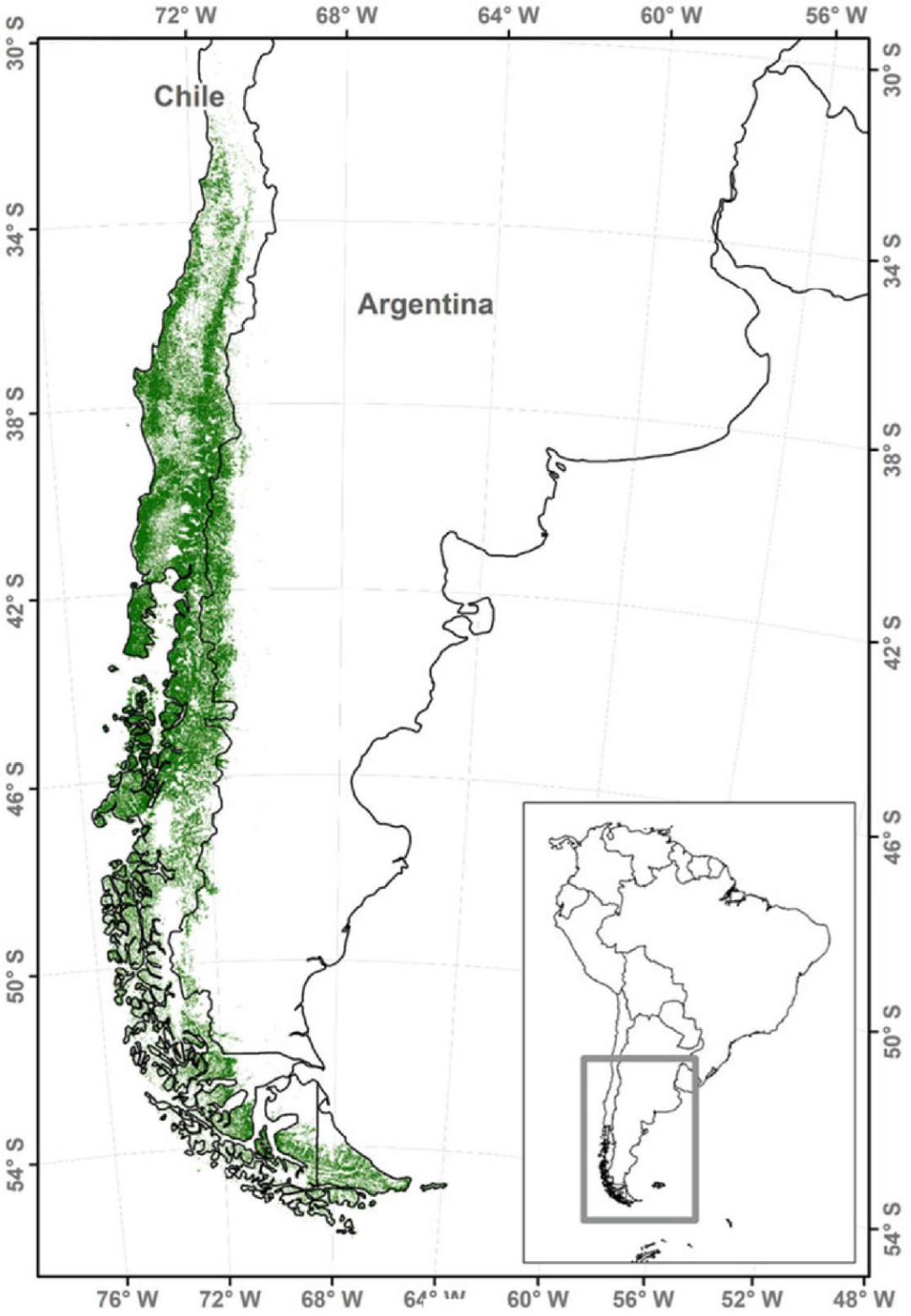


Figure 1 : Distribution of the temperate forest of South America (Loguercio et al., 2018).

3.1 Southern Chile geography

From a broad geographical perspective and for the purposes of this dissertation, Southern Chile refers to the territory located between the Biobío River (37°S) and the Reloncaví gulf (42° S). These limits are not arbitrary, they respond to a series of geographical, ecological, historic, and cultural factors. Although sometimes the northern limit is set in the Maule River (Campbell & Quiroz 2015), the Chilean archaeological community has traditionally taken the Biobío River as the northern border to the Southern Chile Region, also known as Central-South Chile or Extreme South Andean region (Adán *et al.* 2016). In cultural terms, south of the Biobío River is where most of the Mapuche Indigenous population concentrates since time of the conqueror's arrival (1550 CE), and where the Mapudungun language persists until nowadays (Adelaar & Muysken 2004). Historically, the Biobío River was the southern frontier of the Spanish Colonial territory (17th to 18th centuries), and this region was one of the last territories to be incorporated to the Chilean State (1883 CE). In a broad ecological and geographical perspective, Southern Chile as a region shares some climatic, geomorphological, vegetational conditions.

In longitudinal terms, the eastern limit of this territory corresponds to the Argentinian border, delimited by the Andean Mountains, and the western limit is the Pacific Ocean (figure 2). The main geomorphological units that shape this territory are, from east to west, the Andean Cordillera, the longitudinal valley, the coastal mountain range, and the coastal plains (including adjacent islands).

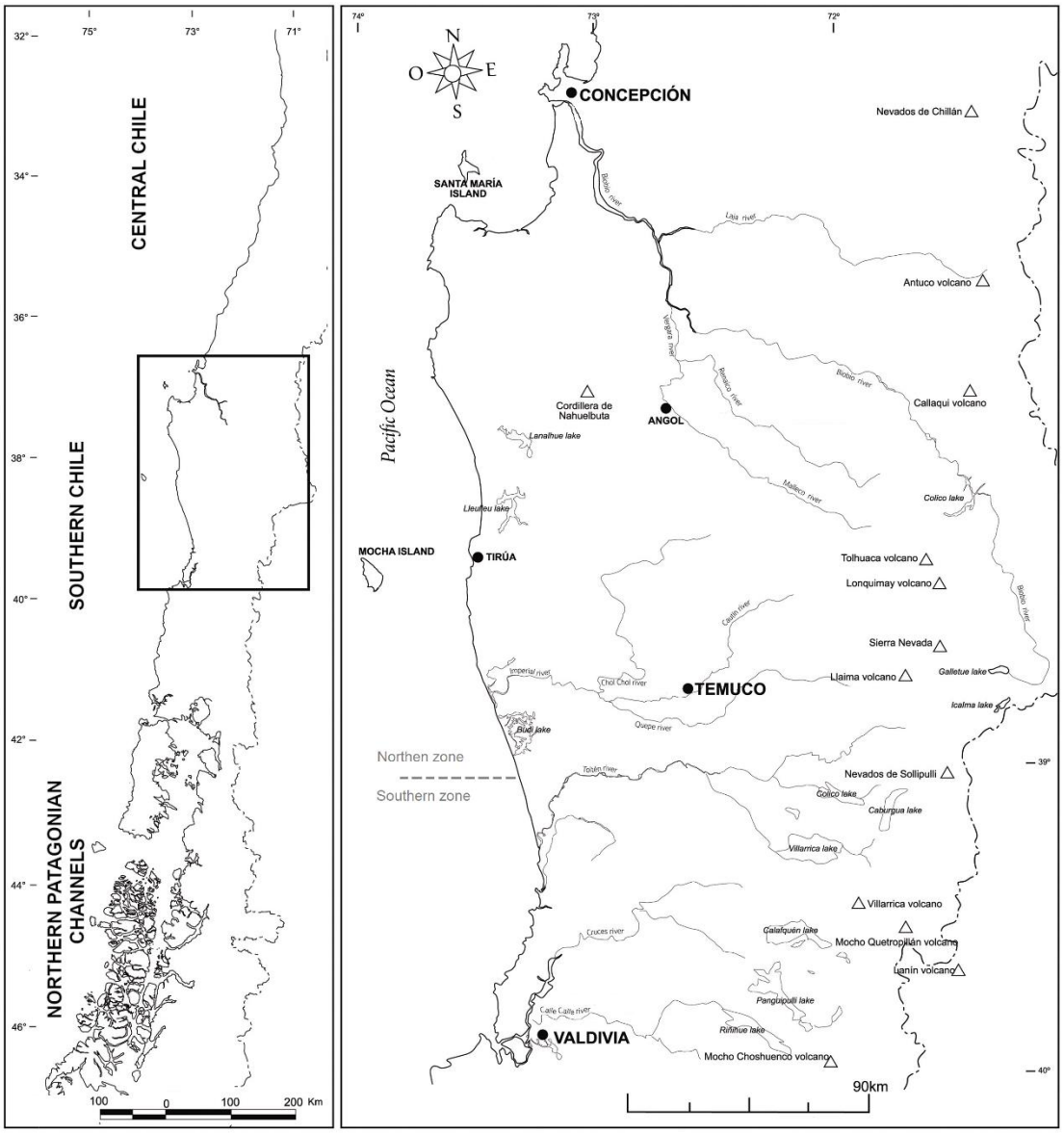


Figure 2 : Map of Southern Chile, black circles indicate modern cities and towns (modified after Campbell et al. 2020).

The Andean mountains present peaks over the 3000 meters above sea level (hereafter abbreviated as m ASL), which usually corresponds to volcanos. Between the mountainous range and the longitudinal valleys, a piedmont or pre-cordillera area is found with elevations between 600 to 1000 m ASL (Campbell & Quiroz 2015). Proglacial lakes are characteristic of this zone, and they originate most of the rivers crossing the longitudinal valleys that then

empties into the Pacific Ocean. The longitudinal or central valley is a fertile and temperate territory where most of the cities and settlements were founded since the Colonial Period. The coastal range receives different names and presents different altitudes (Mardones 2005), from north to south they are: Cordillera de Nahuelbuta (800-1500 m ASL); Cordillera de Mahuidanche (865 m ASL); Cordillera Pelada (1041 m ASL); Cordillera de Espejos (940 m ASL), and Cordillera del Sarao (368 m ASL). The coastal range acts as a climatic barrier diminishing the oceanic influence into the longitudinal valley, and it is the origin of some rivers that end in the ocean. Finally, the coastal plains and adjacent oceanic islands allow access to a variety of marine and littoral resources. The extent of these plains is variable, and in some areas can reach over 25 km of width.

South of the Reloncaví Gulf, the landscape changes abruptly and the predominant forest corresponds to the subantarctic temperate type (Armesto *et al.* 2009b). Due to isostatic processes and glacial erosion, the longitudinal valley is completely and sometimes partly submerged (Maldonado *et al.* 2016). This creates channels and interior seas, and both mountain ranges become a discontinuous territory forming archipelagos. In cultural terms, south of the Reloncaví gulf there was a long tradition of marine hunter-gatherer groups that persisted until historical times.

Today, the Southern Chile region is part of four different administrative political units: Biobío, Araucanía, Los Ríos and Los Lagos. Although for the purposes of the thesis the entire Southern Chile area is included, the archaeological sites

and analysed data comes from the Northern section of Southern Chile: the Biobío and Araucanía regions.

3.2 Vegetation of Southern Chile

Following previous authors, Southern Chile can be divided into a northern and a meridional sector considering the latitudinal Mahuidanche-Lastarria ranges (39°21' S) as a dividing landmark (Adán *et al.* 2016, Aldunate 1989, Campbell & Quiroz 2015), which also corresponds in broad terms to the Toltén River (figure 2). The northern sector includes the Biobío, Imperial, and Toltén rivers basins, and presents a predominance of deciduous vegetation that coexists with sclerophyllous taxa.

The meridional or southern portion includes the Cruces-Valdivia, Bueno, and Maullín rivers basins. In this southern section, there is a predominance of evergreen vegetation that coexists with deciduous taxa (figure 3). The presence of proglacial lakes also characterizes this area. In comparison, while the northern portion of Southern Chile is considered a transitional zone, presenting Mediterranean and Temperate macroclimate units, the southern part corresponds to the Temperate macrobioclimatic unit (Luebert & Pliscoff 2006). This macrobioclimatic divisions also consider the latitudinal and longitudinal climatic differences. In latitudinal terms, there is a marked north to south gradient: while in the northern part of the zone there is a mean annual temperature of 13.3°C and mean precipitation of 1055 mm (reference: Angol station, 37°47’S-72°42’E), at the southern end the mean annual temperature is

10°C and mean precipitation of 1982 mm (reference: Puerto Montt station, 41°82'S-72°56'E). In longitudinal terms, differences are also observed. Considering a similar latitude (38°S), while at the coastal areas the mean annual temperature is 12.3°C and mean precipitation of 1118 mm (reference: Puerto Saavedra station, 38°46'S-73°24'E), at the cordillera the mean annual temperature is 8.4°C and mean precipitation of 1850 mm (reference: Lonquimay station, 38°26'S-71°15'E, Luebert & Pliscoff 2006, p. 29-30).

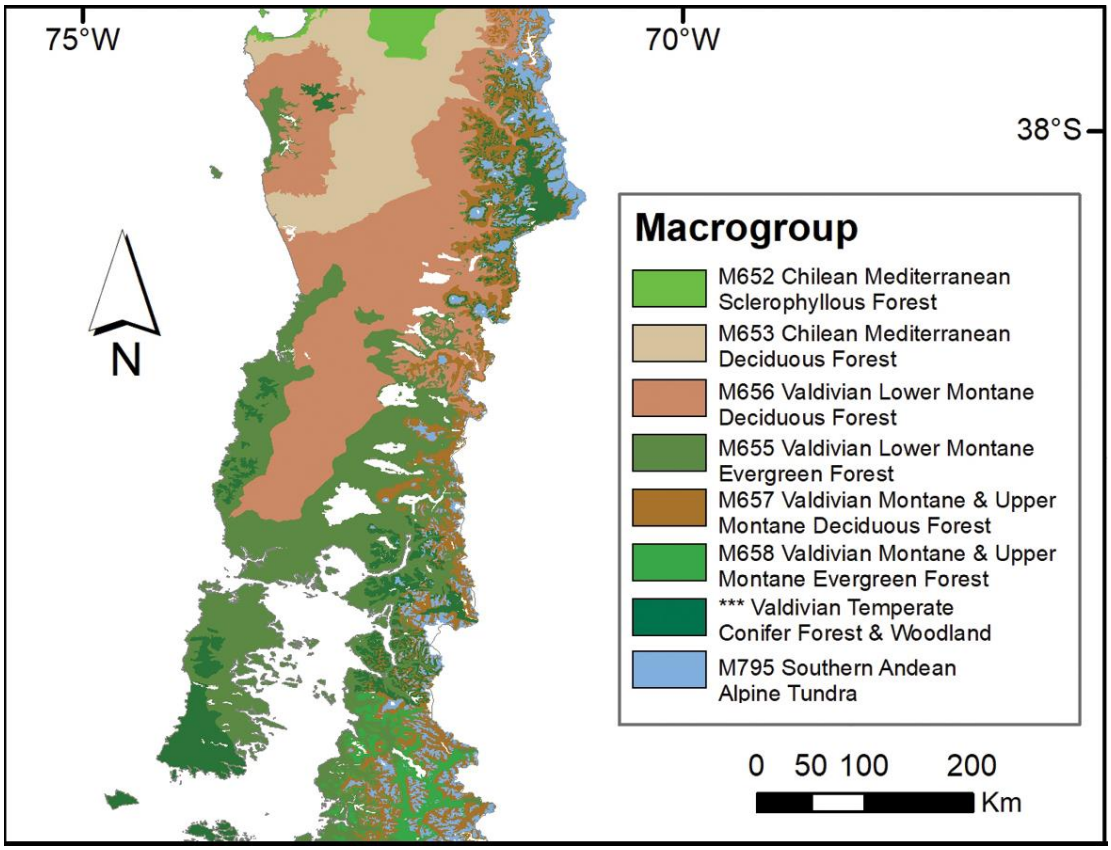


Figure 3: Vegetation macrogroups of Southern Chile (modified from Luebert & Pliscoff 2022).

It is important to clarify that even though the general vegetation corresponds to the Temperate Forests, within these forests there are different levels of classifications. The Mediterranean or Temperate zones allude to the climatic conditions and vegetational conditions, and in each of these zones there are different types of forests. Within the Mediterranean zone the Chilean Mediterranean Forest and woodland division includes sclerophyllous and deciduous forests, and in the Temperate zone the Valdivian Cool Temperate Forest Division includes deciduous, evergreen and conifer forests (Luebert & Pliscoff 2022, p.17). In terms of taxa, while certain species can be found in specific forests, others have a wide distribution range, and they can adapt to different light and humidity conditions. For example, evergreen species can be found in sclerophyllous forest, and deciduous species can form part of conifer forests.

As well as in latitudinal terms, the vegetation is Southern Chile varies according to longitudinal terms. As mentioned earlier in this chapter, geographical altitude has favoured the preservation of the temperate forests. This can be observed in the different forest types found in the Andes and coastal range in comparison to the longitudinal valley. Taking as example the transitional Mediterranean and Temperate zone of Southern Chile (northern section), table 1 shows the forest types in relation to the main geomorphological units of Southern Chile (according to Luebert and Pliscoff´s criteria, 2006).

Table 1: Forest types in the transitional Mediterranean and Temperate zone of Southern Chile

Forest Type	Coastal Range and Plains	Longitudinal Valley	Piedmont and Andes
Mediterranean-Temperate deciduous	*Nothofagus obliqua - Gormotega Keule* forest	*Nothofagus obliqua - Cryptocarya alba* forest	Nothofagus alpina - *Nothofagus* obliqua forest
			Nothofagus pumilio - Nothofagus obliqua Andean Forest
Temperate deciduous	*Nothofagus alpina - Persea lingue* forest	*Nothofagus obliqua - Persea lingue* forest	*Nothofagus alpina – Dasyphyllum diccanthoides* Andean Forest
		Nothofagus obliqua - Laurelia sempervirens forest	*Nothofagus alpina – Nothofagus dombeyi* andean forest
			Nothofagus pumilio - Araucaria araucana andean forest
			Nothofagus pumilio - Azara alpina andean forest
Temperate Coastal	*Nothofagus dombeyi - Nothofagus obliqua* mixed forest		
Temperate Lauriphyllous	*Aextoxicon punctatum - Laurelia sempervirens* coastal forest		
Temperate resinous	*Araucaria araucana* coastal forest		*Araucaria araucana - Nothofagus dombeyi* andean forest
Evergreen Temperate			*Nothofagus dombeyi - Gaultheria phillyreifolia* andean forest

The dominant deciduous tree species in Southern Chile are *Nothofagus obliqua* (Mirb.) Oerst., *Nothofagus alpina (*Poepp. & Endl.) *Oerst., Nothofagus antarctica* (G. Forst.) Oerst., *Nothofagus glauca (Phil.)* Krasser*, Nothofagus pumilio* (Poepp. & Endl.) Krasser (Hoffmann 2005). In the mediterranean and

mediterranean-temperate deciduous forest´s types, sclerophyllous species are frequent. Among the trees, species such as *Cryptocarya alba* (Molina) Looser*, Lithrea caustica* (Molina) Hook. & Arn*., Quillaja saponaria* Molina *and Peumus boldus* Molina are common (Luebert & Pliscoff 2006). Lauriphyllous species are frequent in deciduous and evergreen forest, among the trees, the most important species are: *Aextoxicon punctatum* Ruiz & Pav*., Caldcluvia paniculata* (Cav.) D. Don*, Dasyphyllum diacanthoides (*Less*.)* Cabrera*, Drimys winteri* J.R. Forst. & G. Forst*., Eucryphia cordifolia* Cav*., Laureliopsis philippiana (*Looser*)* Schodde*, Laurelia sempervirens (*Ruiz & Pav.) Tul*., Persea lingue* (Ruiz & Pav.) Nees, and *Weinmannia trichosperma* Cav. Finally, some conifers such as A*raucaria araucana, Podocarpus saligna* D. Don*, Saxegothaea conspicua* Lindl*.*, and *Austrocedrus chilensis* (D. Don) Pic. Serm. & Bizzarri, are found usually in the Andes and Coastal range in association with the evergreen tree *Nothofagus dombeyi* (Mirb.) Oerst.

Special mention deserves the Araucaria forests, today found in areas over the 900 m ASL in the Nahuelbuta Coastal Range and the Andes cordillera (Gajardo 1994). *Araucaria araucana* develops a tick bark that insulates from the heat of fire, becoming one of the native South American tree species that evolved adapted to wildfires (González *et al*. 2020). In cultural terms, the Araucaria forests have great economic importance since pre-Hispanic times (Aldunate & Villagrán 1992). Data from the Argentinian slope of the Andes suggests that the Araucaria nut "*pehuen*" or "*piñón araucano"* has been an important part of the hunter-gatherer's diet since the 3500 BCE (Gordón *et al.* 2018). The ethnographic data indicates that the araucaria forest have been managed for

the procurement of the "*pehuen*", and it is likely that the anthropic fires set by the Mapuche-Pehuenche indigenous people facilitated the north-easternmost extent of the species (Nanavati *et al*. 2020).

One of the characteristics of these forest environments is the high proportion of fleshy fruit among woody plants (70% of the woody flora, including trees, shrubs, vines, and epiphytes). This percentage is higher than the ones from the northern hemisphere temperate forests being similar to some wet tropical forests (Armesto *et al.* 2009b). Among other plant species with edible parts, we count ferns, herbaceous plants, wild grasses, tuberous and fleshy root plants. Because of this diversity of resources, Southern Chile has been described as a suitable environment for human inhabitation (Aldunate & Villagrán 1992). Previous ethnobotanic and ethnographic studies show that indigenous communities have develop a deep knowledge of the forest plant resources (Bragg, Hauenstein & Latsague 1986, Villagran 1998). Reports from the 1900 indicates that around 78% to 97% of the native flora was still used by indigenous people for food and ritual purposes, but also as medicine, fuel, construction and for other different uses (Gumucio 1999, Smith-Ramírez 1995).

Southern Chile vegetation experienced major changes after the second half of the 19th century. The global pre-industrial and industrial demand for timber caused extreme deforestation and soil erosion (mining and the golden age of timber). Later, during the mid-19th century, exotic forestry plantations of *Pinus radiata* D. Don and *Eucalyptus globulus* Labill. were introduced in Southern Chile (related to the paper mill industry) along with intensive crop mono cultivation systems. These events caused a homogenization of the landscape

and limited forest regeneration (Armesto *et al.* 2010). By 2007, the native forest was only 34% of the total territory of Southern Chile. Areas that by 1550 were forests, were turned into agricultural fields (15%) and forestry plantations (14%). Prairies and shrublands had also gained more extension by comparison to 1550 (22% by 2007), and the previous mosaic category characteristic of the indigenous territorial inhabitation pattern was absent (Lara *et al.* 2012, p. 17).

3.3 Paleoclimatic records of Southern Chile

The temperate forest structure and distribution pattern was shaped by the Quaternary climate changes, particularly the ones related to the glacial retreat during the Pleistocene (Villagrán & Hinojosa 1997). After the Last Glacial Maximum (LGM, 21000 to 17000 cal. BCE), paleoenvironmental data suggest the existence of different warm pulses, that correlates with a retreat of North Patagonian- Subantarctic Forest and expansion of taxa indicative of warmer conditions such as the Myrtaceae family (Maldonado *et al.* 2016). If the warmer conditions were sustained continuously after the LMG is still controversial. Some pollen evidence suggests cold and rainy conditions between 17000 and 13000 cal. BCE, showing a predominance of North Patagonian- Subantarctic Forest species such as *Nothofagus dombeyi* and conifers (Villagrán 1991).

Between the 13000 and 8000 cal. BCE more temperate and less rainy conditions were registered. From the 9500 BCE there is clear expansion of warm-temperate vegetation (*Weinmannia trichosperma*), and Valdivian rainforest taxa (*Eucryphia cordifolia, Caldcluvia paniculata*), all more resistant

to draughts than the Myrtaceae familiy (Maldonado *et al.* 2016). These changes in vegetation have also been linked with the increase of paleofires. Prior to 12000 BCE, charcoal abundance is low, but between the 10000 – 6000 BCE there is a maximum in the regional charcoal diagrams driven by changes in the atmospheric circulation and the onset of “El Niño” Southern Oscillation – ENSO - (Moreno *et al.* 2010).

The main influencing factors of the Holocene climatic and oceanographic changes in Southern Chile are the latitudinal shifts of the cool moisture-bearing Southern Westerly Winds (Lüning *et al.* 2019). A southward displacement of the Southern Westerly Winds (henceforth, SWW) results in a warm and dry summer tendency in the study area, together with a rainfall decrease. In contraposition, a northward displacement results in a cool and wet summer and an overall rainfall increase (Fletcher & Moreno 2012).

The early and mid-Holocene presents drier and warmer conditions between 9500 and 4000 cal. BCE. Charcoal peaks were registered in areas with no previous evidence of fires, and there is a clear predominance of thermophilous vegetation (Abarzúa *et al.* 2014). These dry conditions were related to an increase in fire activity during the Early Holocene, and they are attributed to a southward shift and or weakening of the SWW (Nanavati *et al.* 2020). From around the 7500 BCE, in the northern section of Southern Chile (38°- 39° S) these conditions favour the predominance of the Maule type forest (deciduous *Nothofagus* taxa), which suggests probable arid conditions during the summer period (Maldonado *et al.* 2016).

From 4000 cal. BCE, a progressive increase in humidity started establishing the modern climatic conditions, which are considered to be stable over the last 3000-2000 years (Nanavati *et al.* 2020, Villagrán 1991). Pollen data evidence the expansion of temperate humid forest species, related to the moisture increase and decrease of fire activity (Lüning *et al.* 2019). Around the 1600 BCE, a diversity of woody taxa not observed together before has been noticed in the different pollen profiles of Southern Chile. The establishment of sclerophyllous and lauriphyllous species indicative of rainforest, evergreen forest and Maule type forest suggest a higher climatic and environmental heterogeneity than the one observed in the previous periods (Maldonado *et al.* 2016).

The effects of Late Holocene climatic events, such as the Medieval Climatic Anomaly (MCA, 9th to 13th centuries CE) and the Little Ice Age (LIA, mid-16th to mid-19th centuries CE), are still a matter of discussion in the southern hemisphere. As a general trend, South American Paleoclimatic records shows evidence of a warmer period and a peak of fire activity coinciding with the MCA (Lüning *et al.* 2019, Moreno *et al.* 2010). Nevertheless, in the Southern Cone (38°S – 55°S), there is no homogenous signal during the MCA, and while most records confirm warm and dry conditions, there are few other showing wet conditions (Ozán *et al.* 2022).

In Southern Chile, this period was characterized by an intensification of the ENSO from 1000 BCE. The typical *El Niño* conditions, such as rainfall decrease and summer humidity deficit, are linked to the increase of fires frequency around 1500 BCE. The ENSO negative anomalies on summer precipitation

would have caused drought periods potentiating fuel desiccation (Abarzúa & Moreno 2008). The reported charcoal peaks suggest more fire episodes contemporaneous with drought episodes recorded in both Argentina and California (Jenny e*t al.* 2002, Vandenberghe 2012). However, are also studies in the region reporting periods dominated by *La Niña* conditions (also referred as *El Niño* wet phase), which in contrast, are indicative of a summer moisture surplus (Ozán *et al.* 2022).

In relation to the LIA, different proxies (such as lake sediment cores, peat climatic records, and historical records) have indicated rainfall increase and lower temperatures in Southern Chile and Patagonia for the period. This could represent a regional expression of the LIA (Araneda *et al.* 2009, Chambers *et al. 2014*). Nevertheless, recent studies show local deviations in timing usually attributed to a northward expansion of the SWW but could also be related to different geomorphological settings (Aravena *et al.* 2006).

A study combining pollen and charcoal data from the Andean region of the Araucanía (38°S) indicates warm and dry conditions between 356-556 CE and 865-1225 CE which fits well with the Roman Warm Period and the MCA, respectively (Fletcher & Moreno 2012). The same study also shows periods of growing moisture and lower temperatures between 556-856 CE and 1225-1829 that fits the Dark Ages Cold Period and the LIA.

Overall, the paleonviromental information of Southern Chile is still fragmentary and concentrated in the Cordillera and piedmont. This area concentrates most of the lakes and lagoons, and since most of the paleoenvironmental profiles come from lake or lagoon sediments, this concentration responds to

geographical factors. In chronological terms, the high resolution of most paleoenvironmental studies becomes a concern, especially after the Ceramic Period (400-1550 CE), since the Early, Late, and posterior Historic Period are just some centuries apart. In these archaeological schemes, even the σ variation of the radiocarbon dates can have significant chronologic implications from one period to another.

The only paleoenvironmental studies closely related to archaeological time scales are two multiproxy studies (Abarzúa 2009, Abarzúa *et al.* 2014): one conducted in the Puren-Lumaco Valley (central longitudinal valley, 38°S), and the other in the Budi Lake (coast, 39°S). The results of both locations show human-related environmental changes during the Late Holocene. The authors report pollen of cultivated plants from 3000 BCE (such as Chenopodiaceae, Solanaceae, Asteraceae, Fabaceae, Poaceae, and traces of *Zea mays*), along with a drop of arboreal taxa and an increase of charcoal peaks. The high phosphorus concentration after 3000 BC was interpreted as soil erosion caused by turning the native forest into agricultural fields. The last 2000 years of the sequence from the Purén-Lumaco Valley show an increase of Poaceae and Nothofagus pollen, as well as a relative rise in woody sclerophyllous taxa.

3.4 Fire history and vegetation in Southern Chile

In the temperate forests of America, lightning is the principal ignition source for wildfires. Volcanic eruptions are also an ignition source of wildfires, but these

fires are usually geographically restricted to the Andes Cordillera (Úbeda & Sarricolea 2016). In comparative terms, lightning frequency is lower in South America than in North America. Previous pollen studies have proposed that the occurrence of fires during pre-Hispanic times was associated with human activities (Abarzúa & Moreno 2008). Under this perspective, fire frequency was supposed to be low before human inhabitation, or at least not high enough to generate an evolutionary pressure in the native species (Veblen *et al.* 2006). Although there are fire-resistant trees and fire-adapted sprouting species (Alaback *et al.* 2003), a low wildfire frequency could in part explain why the south American vegetation has developed less adaptation to fire than the species from the temperate forest of North America (Armesto & Pickett 1985, Holz & Veblen 2011).

Fire occurrence in Southern Chile is facilitated by dry conditions related to regional-scale summer drought, suggesting that climate factors are more relevant than ignition limitation (González *et al*. 2020). Dendrochronology records from the cordillera area show that fire events are significantly related to years of warm and dry summers following ENSO years. During *El Niño* years, the positive precipitation anomalies during late spring allow the development of a grass cover that later will act as fine fuel. Fire occurrence is fuel-limited in the eastern slope of the Andes and seems to be dependent on fine fuel availability for its occurrence and spread (Úbeda & Sarricolea 2016). According to Armesto *et al.* (2006), bamboo plants can also affect the fire regimes by altering fuel availability. The native *Chusquea* bamboo is highly

flammable, and their long and tall culms can rapidly drive fire to the forest canopy.

Because natural wildfires are uncommon in Southern Chile, the evidence of unprecedented charcoal peaks in sedimentary records, along with the presence of disturbed environment indicators are usually interpreted as the result of anthropic burning (Abarzúa 2009, LeQuesne, Villagrán & Villa 1999). From paleoenvironmental records from the Purén-Lumaco Valley, it has been suggested that a progressive environmental disturbance started from around 3000 BCE, indicated by charcoal peaks, decreases of arboreal taxa, and presence of exogenous taxa in fossil pollen records (Abarzúa 2009, Abarzúa *et al*. 2014). In environmental terms, this period of increased fire activity might be affected by the onset of highly variable regimen of summer (Abarzúa & Moreno 2008). It should be noted that the period fits with the Late Archaic Period in the archaeological chronology of Southern Chile (2000 cal. BCE to 400 cal. CE), nevertheless there is not conclusive evidence supporting a causal relationship between the fire occurrence and human activities. Previous studies that have tried to discriminate between human and climate effects on wildfire activity in Patagonia (42°S-48°S) have concluded that it is still difficult to separate the anthropic influence from climate variability, and even though there is no causal evidence, they could be correlated (Holz and Veblen 2011, Mendez *et al.* 2016).

Independently of its frequency and its natural or anthropic origin, fire is an important driver of the vegetational change. The expansion of shade intolerant trees such as *Weinmannia trichosperma* observed in different pollen profiles from around the 9500 BCE was near-synchronous with the intense fire activity

documented from the 10000 BCE. This fire disturbance can also be indicative of volcanic regimens, and *Weinmannia trichosperma* has been grouped along others shade intolerant tree taxa, such *Eucryphia/Caldcluvia, Tepualia stipularis,* and *Nothofagus* (Moreno, Gonzalonera & Hernandez 2014), as Disturbance Favoured Trees since there is positive feedback between fire disturbance and the increase of these taxa.

In successional terms, forest recovery after a fire depends on specific ecological conditions. The regrowth of Mediterranean species after a fire is irregular, even though some evergreen shrub species can germinate under fire-induced heat. Although some of the mediterranean woody species can withstand fire, the presence of post-fire herbaceous species causes competition for moisture and light, and some of the previous species growing as trees can regrow as shrubs (Veblen & Alaback 1996). Overall, the sclerophyllous species of old-growth stands lack the ability to recolonize immediately after fire disturbance, allowing pioneer species to colonize and changing the original forest configuration (Armesto & Pickett 1985). Among the pioneer species of the sclerophyllous forest there are tree species of the Fabaceae family (*Acacia caven* (Molina) Molina, *Sophora macrocarpa* Sm., shrub species of the Asteraceae family (*Baccharis spp., Gutierrezia resinosa* (Hook. & Arn.) S.F. Blake) and other shrub species like *Colliguaja odorifera* Molina*, Colletia hystrix* Clos, *Muehlenbeckia hastulata* (Sm.) I.M. Johnst*. (*Armesto & Pickett 1985, Rundel 1981).

In the lauriphyllous forest, the tree species that colonize after a fire event are usually from the *Nothofagu*s genus (deciduous species), and as the awareness

of the previously underestimated effects of pre-Hispanic burning practices increases, *Nothofagus* forests have been attributed to frequent fire disruption since the pre-Hispanic period. Their wide distribution, especially along the longitudinal valley shows evidence of the long-term interaction between the native indigenous populations and the temperate forest environment (Otero 2006, p. 33)

If the fire occurred in an area with an abundant presence of *Chusquea* bamboo, they are likely to resprout rapidly after the fire impeding immediate tree regeneration until a synchronous flowering and subsequent die-off of the *Chusquea* bamboo. Forest areas with a dense canopy and an absence or few specimens of Chusquea are more likely to allow the development of even-aged stands of shade-intolerant tree species like *Nothofagus sp., Weinmannia trichosperma,* and *Eucryphia cordifolia* (Úbeda & Sarricolea 2016). Eventually (after approximately 300 years), shade-tolerant species will develop under the shade-intolerant canopy. Later on, and only in absence of further disturbance, the successional trend will show a predominance of shade-tolerant species (*Laurelia sempervirens, Laureliopsis philippiana, Persea lingue, Aextoxicon punctatum*, and Myrtaceae trees).

Even though vegetation is directly related to soil conditions, there are few studies concerning the effects of fire on native forest soils (Armesto *et al.* 1996). In coastal ecosystems, fire effects are more aggressive. Along with the burning of biomass, fire causes a significant loss of organic soil by altering the biological mechanisms of nutrient soil retention (Díaz, Bigelow & Armesto 2007). Since most pioneer and shade-intolerant species cannot colonize o regenerate

efficiently and extensively on poor soils, secondary vegetal associations of shrubs and bushes develop (typical species are *Baccharis* sp. and *Aristotelia chilensis* (Molina) Stuntz), impeding the regeneration of the original forest cover (Villagran 1991). In isolated places with an absence of the *Nothofagus* genus (Mocha Island is a case discussed in chapter seven), fire also interferes with the restoration of the coastal *Aextoxicon punctatum* hygrophilous forest by promoting secondary bushes that do not allow a natural forest recovery (LeQuesne, Villagrán & Villa 1999).

Chapter 4: Southern Chile archaeological context

4.1 Southern Chile archaeological chronology

In order to facilitate a general compression of Southern Chile's archaeological chronology, an illustrative synthesis is presented in figure 4. Also, I would like to clarify that although there is still an ongoing discussion on the matter (Dillehay 2007, 2014), in this dissertation there is no mention of the Inca or Tawantinsuyu (1450 CE). According to the historic record, the Maule River (35°S) was the southern frontier of the Inca expansion in Chile (Uribe & Sánchez 2016), and currently there is no direct archaeological evidence of the Inca influence or presence in Southern Chile. Similarly, other cultural influences such as the Polynesian presence in Southern Chile are reviewed briefly and not addressed deeply because the evidence is controversial (Buhring *et al.* 2023, Ramírez-Aliaga 2022).

Other necessary clarification is the terminology used among archaeologists in Southern Chile. Since the terms used in this dissertation are translations from Spanish expressions, they do not necessarily mean the same in English or sometimes they are used in a different way. The term complex (*complejo* in Spanish) refers to a cultural complex and it is used to encompass different aspects of an archaeological culture, such as the material culture, subsistence strategies, funerary and symbolic practices. Although until the 1990's the term complex was mainly used in relation to funerary or ceramic complex (*complejos funerarios y complejos cerámicos*), today it is used in a broader cultural sense (Lema 2018).

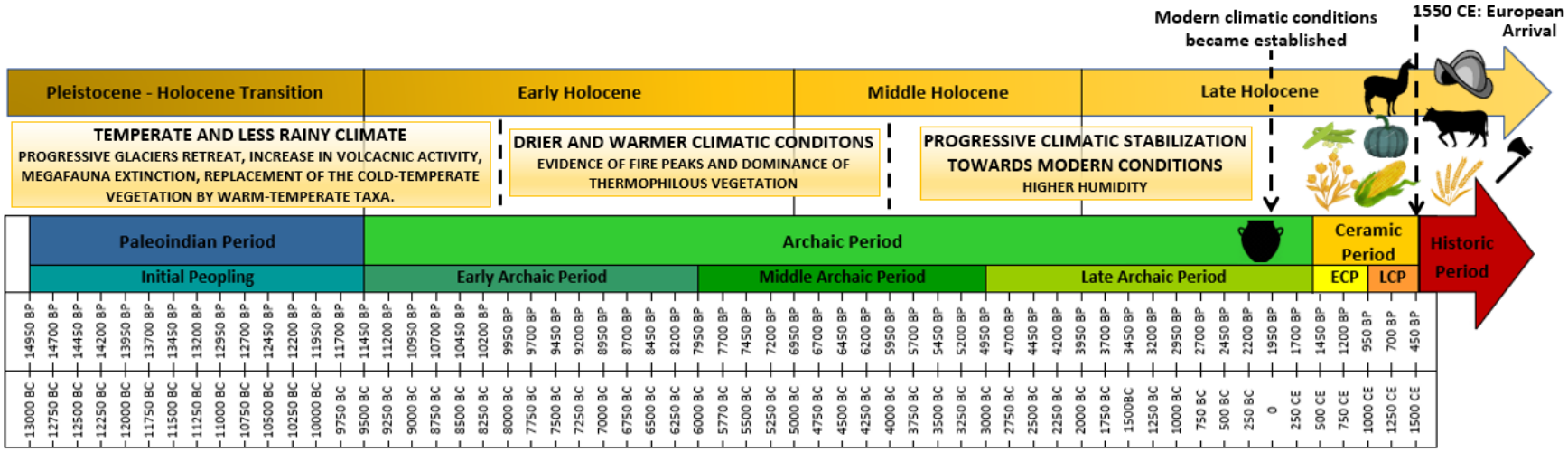


Figure 4 : General chronology of Southern Chile.

Other terms such as tradition are less standardized, and their use and meaning varies depending on each author. In the broad sense, traditions mostly refer to a technological tradition, such as a ceramic tradition (Falabella *et al.* 2015) or a navigational tradition (Lira 2007). But other authors such as Adán, García and Mera (2010), use the term archaeological tradition to refer to a continuity of practices that are not necessarily related to a specific technology, and that can be understood as a cultural tradition.

The earliest archaeological contexts of Southern Chile correspond to the Paleoindian Period (15000 to 9500 cal. BCE). Sites of this period, like Monte Verde II and Pilauco, are characterized by an expedient and non-formalized lithic technology, and the presence of extinct and/or modern faunal remains (Núñez *et al.* 2016). In terms of subsistence, other types of organic materials are scarce. The only published evidence of vegetal remains was founded in Monte Verde II (14220-13980 BCE), where a series of seeds, seaweed, fruits, and other plant parts with edible and medicinal characteristics were recovered along with wooden structural remains, leather, and animal hide (Dillehay *et al.* 2008).

The Pleistocene-Holocene transition marks the end of the Paleoindian Period, and the beginning of the Archaic Period. Few sites are reported for this last period, and there seems to be an “archaeological gap” in the Early Archaic Period between 9500 and 6000 cal. BCE (Quiroz and Sánchez 2004). For the following Middle Archaic Period (6000 to 2000 BCE), there are a series of sites registered in coastal areas, but few of them in the valley and cordillera areas. The presence of more coastal settlements after the 6000 BCE has been linked

to the stabilization of the sea level after the Holocene Marine Transgression which could also explain the “archaeological gap” of the Early Archaic Period. Although the records for this phenomenon are variable along the Chilean coast (from 3-5 meters above sea level at 30°S to 33 meters above sea level in Mocha Island 38,4°S, Abarzúa 2009), the general understanding is that there was a significant rise of the sea level in Southern Chile. Following this logic, if there are pre-6000 BCE coastal sites, they could be undetected because they might be underwater today (Adán, García & Mera 2010).

Most of the Middle Archaic sites are large shell middens with multiple strata layers (indicative of either recurrent or long-term occupations), and the material assemblage shows specialization towards coastal and marine resources (Adán *et al.* 2016). Some of the few sites documented in the cordillera (Marifilo-1 and Loncoñanco 2) suggest a recurrent occupation of the rainforest environment (Adán, García & Mera 2010). Even though the archaeological evidence of the Archaic Period presents spatial and temporal gaps (Campbell & Quiroz 2015), a “Temperate Forest Archaeological Tradition” (*Tradition arqueológica de los Bosques Templados*) has been proposed based on the long chronological sequence of dated sites located near proglacial lakes (Andean piedmont). The recurrent occupation of the rainforest environment has been interpreted as evidence of well adapted hunter-gatherer groups, who developed high mobility strategies leading to an efficient use of forest resources (Adán, García & Mera 2010). Direct archaeobotanical and zooarchaeological evidence indicates the consumption of tree fruits (*Peumus boldus*) and wild grasses (*Bromus cf. mango/uniloides*), along with freshwater molluscs (*Diplodon chilensis*), and

small mammals (*Pupu pudu, Hippocamelus bisulcu, Pseudalopex griseus*). Even though direct archaeobotanical evidence is scarce (Lehnebach *et al.* 2008), traceology and experimental approaches suggested that woodworking was one of the main activities carried out at these Andean piedmont sites (Cordero 2009).

During the Late Archaic Period (2000 cal. BCE – 400 cal. CE), more geographical areas show evidence of occupation, including some oceanic islands between the 1872 to 1135 cal. BCE. Nevertheless, there seems to be an occupation hiatus in the coastal areas between 1135 and 340 cal. BCE (Campbell & Quiroz 2015). In comparison with the previous periods, more sites are documented in the longitudinal valley (particularly in the Purén-Lumaco valley and the Quillen River basin), and in the cordillera area (including the Andean piedmont near the Calafquén and Villarica lakes). This suggests a more intensive and extensive use of the territory and its resources. During this Period, ceramics start appearing in the archaeological record. Direct thermoluminescence dates of these early fragments indicate a Late Archaic adscription (565 BCE - 295 CE), which has also been corroborated with paired ^{14}C dates (Adan & Mera 2011).

The Early Ceramic Period (401-1000 CE) has been described based on the Pitrén Ceramic Complex and includes a ceramic tradition as well as funerary practices (although some other different early ceramic traditions have been proposed for the Arauco Gulf area, Adán *et al.* 2016). The populations of this Period have been characterized as small bands of high mobility hunter-gatherers with ceramic technology and horticultural practices. Although there

are records of Early Ceramic sites in all the geographic areas, due to the archaeological research history, most of the studied sites are concentrated on the coast and the valley of the northern area of Southern Chile (37°-39°S). Despite this archaeological bias, the geographical position of the reported sites suggests a more extensive use of the territory, and a possible rise in population density by comparison with the Archaic Period (Campbell & Quiroz 2015). Regarding the Andean piedmont, some of the sites around the Calafquén Lake show a continuous occupation from the Archaic to the Early Ceramic Period. This indicates a recurrent occupation of the rainforest environment, suggesting a traditional way of life adapted to this environment and proposed as the Archaeological Tradition of the Temperate Forest (Adán, García & Mera 2010).

Most of the available information for the Early Ceramic Period comes from funerary contexts presenting crouched inhumation patterns (Aldunate 1989). The ceramic typology data derives mainly from grave offerings, which include symmetric and asymmetric vessels with one or more decoration techniques such as modelling, red split/paint, and negative decoration. Pottery is considered the most diagnostic feature of the Pitrén Complex; most of the vessels have portable sizes (including miniatures) and its broad distribution reflects wide interaction circuits. Ceramics ascribed to the Pitrén Complex have been registered in archaeological sites in the Andes eastern slope (Neuquén Province, Argentina), along with archaeobotanical evidence of crops (Pérez & Erra 2011). Also, foreign elements such as metallic ornaments and woven textiles made of alpaca wool (*Lama pacos,* syn. *Vicugna pacos*) found in a funerary context in Villa JMC-1 (Cautín River basin) show similar attributes to

some registered in the Chenque I site of La Pampa Province, Argentina (Adán *et al.* 2016). Although there is no direct evidence of Pitrén groups reaching as far as the Pampa province (about 800 kilometres distance), the archaeological materials indicate a fluent communication between both slopes of the Andes Cordillera (Roa *et al.* 2018). In terms of subsistence, zooarchaeological remains and isotopic studies evidence the consumption of small mammals (presumably acquired by hunting or trapping), seafood, riverine and lake resources (Adán, García & Mera 2010). Archaeobotanical evidence suggests the gathering of wild fruits and nuts, along with the cultivation of quinoa and maize (Lehnebach *et al.* 2008, Roa *et al.* 2018).

Around the 1000 CE, a series of socio-economic changes are evidenced in the archaeological record of the northern zone of Southern Chile, marking the beginning of the Late Ceramic Period. This period is also known as “El Vergel” Complex, and it has been described as a period of emerging social complexity and social differentiation (Campbell 2011, Dillehay *et al.* 2007). Although there are sites in the meridional zone of Southern Chile and the Andean cordillera and piedmont with dates after 1000 CE, their archaeological context does not represent the changes characteristic of the Late Ceramic Period. Therefore, a persistence of the Pitrén Complex after the 1000 CE has been proposed for the meridional zone of Southern Chile and the northern cordillera sector (Campbell & Quiroz 2015).

As well as the Pitrén Complex, El Vergel was initially based on funerary contexts showing a differentiation with the previous burial traditions of the Early Ceramic Period. Inhumation patterns show diversification, along with the

presence of different ceramic vessel offerings showing a painted bichrome decoration ("red over white" type). Other materials, such as metallic ornaments became more frequent in the archaeological record (Campbell 2015). The predominance of camelids bones among the faunal remains has been interpreted as a predilection of camelid consumption (*Lama spp*.), and the presence of textiles made of llama fibre (*Lama glama*) and alpaca wool (*Lama pacos*) could suggest domestication/taming practices (Navarro & Aldunate 2002).

Although there is crop evidence since the Early Ceramic Period, after 1000 CE crop production was intensified (Roa *et al.* 2018), and some authors have proposed the existence of raised platforms and canalized fields (Dillehay *et al*. 2007, 2020). The intensification of crops (such as quinoa, common bean, and maize) and native grasses (*Bromus mango* E. Desv., *Bromus berteroanus* Colla, and *Bromus catharticus* Vahl.), might be related to population growth. This correlates with the larger number of reported sites in the northern zone of Southern Chile and the paleodemography estimations based on the chronological database of Southern Chile (247 ^{14}C dates, 148 thermoluminescence dates, and 3 obsidian hydration dates, Campbell & Quiroz 2015). The presence of public architectural landmarks (mounds or *kuel*) also indicates the existence of social aggregation and ritual practices (Campbell 2011), associated with the evidence of large ceramic containers related to food storage for festivities and social aggregation events (Adan *et al.* 2016), both supporting population growth.

Regarding the spatial distribution of settlements and residential patterns, the coast and the central valley shows a continuous occupation from the Early to the Late Ceramic Periods. Some archaeological sites evidence a stratigraphic sequence encompassing both periods, indicating an intensive spatial occupation and spatial continuity through both periods (Campbell & Quiroz 2015). The Pitrén-El Vergel continuity has also been proposed from a ceramic evidence perspective. Although El Vergel ceramics present different decorative styles, part of the ceramic assemblage maintains the vessel shape, morphometry, and technical aspects of the Pitrén Complex (Adán *et al.* 2016).

The end of the Late Ceramic period and the beginning of the Historic Period was marked by the arrival of the Spanish Conquerors to Southern Chile in 1550 CE. During the following decades, several forts and villages were founded by the Spaniard conquerors south of the Biobío River. The continuous indigenous uprisings caused the destruction of the Spanish settlements and lead to its consequent abandonment by 1604 (Campbell 2011). In 1641 the Spanish crown signed a treaty recognizing a native independent territory between the Biobío and Toltén rivers.

Archaeology of historic times is still underdeveloped in most of the region, and most of what is known about the Historical Period comes from the records written by missionaries, explorers, and conquerors. At the time of the European arrival, the ethnolinguistic diversity was represented by the Mapuche or Araucanian languages, which have persisted into the modern Mapudungun language and the endangered Huilliche language (Adelaar & Muysken 2004). The early written testimonies indicate that during the following centuries the

native populations were denominated Araucanos instead of the ethnonym *reche* (*re: puro, real, original* translates as real or original in English; *che: gente* translates as people in English), which can be translated as the authentic people or true people (Boccara 1999, p. 427). Around the 18th century, the term *Mapuche* becomes frequent and has been used since then by the indigenous populations to refer to themselves (Campbell 2011, Dillehay 2010). As a term, *Mapuche* can be translated as people from the land or earth (*Mapu: tierra* translates as land or earth in English). Although there is not explicit consensus, some authors use *Reche-Mapuche* to refer to the native indigenous populations of the Historic Period before 1882 (Campbell 2011, Goicovich 2018). *Mapuche* then is mostly used to refer to the ethnographic populations from the 19th century onwards, and as a term, it could be used to encompass different groups. In geographical terms, the *Mapuche* population has historically occupied the central Valley, while the *Pehuenche* groups have lived on both slopes of the Andes cordillera and the cordillera piedmont (*pehuen* is the *piñon* or pinenut from *Araucaria araucana*). *Lafkenche* groups have inhabited the coastal plains, especially around coastal lakes, like Lanalhue, Lleu-Lleu, and Budi Lakes (*lafken* can be translated as lake or lagoon). Huilliches groups, on the other hand, have traditionally lived in the most meridional portion of Southern Chile, including the Chiloé archipelago (Aldunate 1996). The Chilean Indigenous Law (n° 20117) acknowledges all these different groups as part of the Mapuche group (*pueblos originarios*), although there have been previous legal initiatives to recognize the Huilliche populations as a separate group.

The early historic *Reche-Mapuche* sites present continuity of practices from the Late Ceramic Period, but they also reflect the adoption of European elements (Adán 2014). The introduction of cattle, wheat, and barley had a significant economic impact on the *Reche-Mapuche* society, enabling production surplus. According to early written records, by the 16th century, the main economic activities of the *Reche-Mapuche* were agriculture and camelid husbandry. By the 18th century, the main economic activity was exotic livestock husbandry (ovine, bovine, and equine) and the commerce of the textiles made from them, primarily sheep wool (Boccara 1999, p. 441-448).

The Chilean emancipation from the Spanish Crown started in 1810. The free-Indian country south of the Biobío persisted until 1882 when the Chilean army overcame the last standing areas of indigenous resistance during the "Pacificación de la Araucanía" military campaign (1850-1882). After 1882, the Chilean state forced the Mapuche populations to reduce their territories, creating indigenous reservations (Sauer 2015, p. 74). Through the loss of territory and their resources, state policies caused the economic impoverishment of these communities. Most of the traditional knowledge related to the different uses of the temperate forest resources comes from the Mapuche Culture. Also, most of the ethnographic analogies used in the archaeology of Central and Southern Chile are based on ethnography and ethnoarchaeology of Mapuche communities (Campbell 2011, Sanhueza, Cornejo & Falabella 2007, Toro 2022). Several ethnographic, ethnohistorical, and ethnobotanical studies have highlighted the close relationship between the Mapuche cosmovision and its landscape, not only in utilitarian terms but also

acknowledging the symbolical and ritual sphere associated with the environment and its resources (Adán *et al.* 2004, Villagran 1998). Although several aspects of the Mapuche culture have changed over the centuries, other elements show continuity from pre-Hispanic times.

4.2 The spread of farming in Southern Chile

According to the written records of the 16th century, the native populations of Southern Chile had gardens close to their houses, where they cultivated maize (*Zea mays* L.), potatoes (*Solanum tuberosum* L.), quinoa (*Chenopodium quinoa* Willd.), chili pepper (*Capsicum baccatum* L.), squash (*Cucurbita maxima* Lam.), and beans (*Phaseolus vulgaris* L.), along with local grasses and species like *mangu* (*Bromus mango* E. Desv.), *teca* (*Bromus berteroanus* Colla), *lanco* (*Bromus catharticus* Vahl.), and *madi* (*Madia sativa* Molina) (Silva 2014). Nevertheless, there is a consensus regarding the agricultural emphasis of the early written records and the neglected role of the wild gathered resources (Roa *et al.* 2018).

In chronological terms, wild vegetal resources appear in the archaeobotanical record from the Archaic until the Historic Period. Cultivated plants start appearing in Southern Chile during the Early Ceramic Period, and they were probably initially domesticated in other areas, but when and where these crops were first acquired and how they were dispersed across this southern territory is still a matter of discussion (Planella *et al.* 2014). Earlier perspectives proposed a gradual north to south crop dispersion, since the initial comparison

show a higher number of different cultivated plants in the Northern areas, as well as earlier dates than in the southern zones. Cultivated plants start appearing in the archaeological record around the 2000 BCE in the arid north of Chile (Castro et al. 2016), and in the central mediterranean zone the earliest evidence of crops corresponds to quinoa dated to the 1000 BCE (Falabella *et al.* 2016). The latest archaeobotanical analysis indicates that crop dispersion involved multiple regions on both sides of the Andean range rather than simply taking place following a north-south pattern (Pérez & Erra 2011).

The evidence from the closest geographical zones to the study region suggests that crops were introduced to Southern Chile from northern areas. According to the archaeological record, domesticated plants as maize (*Z. mays*), squash (*Cucurbita spp.),* and gourd (*Lagenaria siceraria* (Molina) Standl.) were frequent in the south of the Mendoza Province (eastern slope of the Andes) by the 50 CE (Gil 2003). Then by the 400 CE they become frequent in Mediterranean Central Chile, and around the 900/1000 CE they are ubiquitous in Southern Chile (Roa *et al.* 2018). The earliest evidence of quinoa found in central Chile shares morphological traits with those registered in the Cuyo-Mendoza Provinces (Planella *et al.* 2014). This type of quinoa is described as "sea level quinoa", to differentiate it from the "Altiplano quinoa" common in the arid north zone and found in later contexts of Central Chile (around 1000 CE). In general terms, the "sea level quinoa" or "coastal quinoa" correspond to ecotypes adapted to low altitudes (0-300 m ASL.), that have relict attributes associates to the wild predecessors and show a smaller grain size than the Altiplano types (Planella 2019). Considering the frequent contact between both

sides of the Andes (Campbell, Roa & Santana 2018, Gil *et al.* 2006; Pérez & Reyes 2009), crops could have been introduced to central Chile from west-central Argentina and later dispersed further south, reaching Southern Chile.

South of the Reloncaví gulf, few studies have addressed the crop dispersal topic. It has been proposed that around the 1000 CE marine hunter-gatherer and sedentary groups coexisted in the Reloncaví Gulf and Chiloé Archipelago, and the marine hunter gatherer groups from farther South in the Patagonian channels were in contact with groups who already managed animals and crops (Aldunate 1996, Belmar *et al.* 2021, Massone *et al.* 2016). The most recent archaeobotanical data comes the Chiloé and Chonos Archipelago (Belmar *et al.* 2021, 2023). Micro remains analysis (including dental calculus, starch and phytoliths analysis), have indicated the circulation of domesticated plants such as beans (*Phaseolus vulgaris*) since around the 1400 CE (there are earlier dates from around the 400 CE, which the authors attribute to possible wide interaction networks). Maize and potato were found in later contexts (post-1400 CE) ascribed to the Late Ceramic and Historic Periods. While most of the contexts from Chiloé archipelago could suggest the presence of Late Ceramic groups planting and cultivating in the Archipelago, the more southern data from the Chonos Archipelago indicates consumption but not necessary cultivation (since they could have obtained these plants by exchange). The archaeological research from the Patagonian Channels indicates that populations maintained a highly mobile hunter-gather economy even after the European expansion. Subsistence was based on wild coastal and terrestrial resources, with no evidence of pre-Hispanic cultivated plants.

At the western slope of the Andes, evidence of agriculture is found until the south of the Mendoza province in Argentina (36°S), approximately at the same latitude as the Mediterranean central zone of Chile. Farther south, in the Argentinian Northern Patagonia (same latitude as Southern Chile), there is archaeobotanical evidence of cultivated plants but the groups who inhabited the area have been described as hunter-gatherers until post-contact times (Ciampagna & Capparelli 2012). The isotopic values from this region evidence a highly mobile lifestyle with a diversified diet where C4 plants were not a staple element (Gil, Neme & Tykot 2010). Taking also in consideration other aspects of the material culture, the evidence suggests wide exchange circuits where domesticated plants, such as gourds and maize could have been obtained from the south of the Mendoza province (Lema, Negra & Bernal 2012), or from Southern Chile (Musaubach & Berón 2012). The only pre-Hispanic evidence indicating crop domestication in the eastern slope of the Andes is found in areas near the cordillera in the Neuquén Province, but the material contexts suggest a dispersal of Southern Chile populations rather than Patagonian groups engaging crop cultivation (Pérez & Erra 2011, Pérez, Reyes & Erra 2013).

The archaeobotanical evidence of Southern Chile suggests that the most important pre-Hispanic crops were quinoa, maize, and common beans. The reduced archaeobotanical evidence for the Pre-Ceramic Period suggests the exploitation of wild resources (Lehnebach *et al.* 2008). Evidence of cultivated plants such as quinoa (*Chenopodium quinoa*) and common bean (*Phaseolus vulgaris*) has been registered from the Early Ceramic Period. The earliest taxon

date of a cultivated plant (direct date of taxonomically identified specimen as opposed to stratigraphic association with other remains) was obtained from a *Phaseolus* sample from Cueva de los Catalanes (680-860 cal. CE). In the same context, quinoa grains were obtained in stratigraphic association the dated Phaseolus samples (Roa *et al.* 2018). Around the 1000 CE, during the Late Ceramic Period, cultivated plants become more frequent in the archaeological record, nevertheless, less taxa have been registered in comparison to Central Chile, and even less if comparing to the Arid North. The cultivated plants registered during the Late Ceramic period are quinoa (*C. quinoa*), common bean (*P. vulgaris*), chilli pepper *(Capsicum sp.)* squash (*Cucurbita sp.),* maize (*Z. mays*), wild grasses (*Bromus sp.),* madi (*Madia sativa*), and possible potato (*Solanum sp*.). The most ubiquitous cultivated plants are quinoa and maize. The low ubiquity of common bean might be due to taphonomical factors, as these beans require minimal crop-processing compared to cereals and pseudo-cereals; their large seed size also means they are less likely to be lost compared to small seeds, such as quinoa. Squash (*Cucurbita sp.*) has only been recovered in one site of the Puren-Lumaco Valley. However, squash and quinoa seeds were present in a Late Ceramic funerary urn found in 1991 at Alboyanco, but archaeologists did not excavate the context, and the seeds were not analysed or kept for future analysis (Navarro and Aldunate 2002). Chilli pepper has only been recovered in Cueva de Los Catalanes (Roa Solís e*t al.* 2024). In relation to the cultivated native grasses (*Madia sativa, Bromus mango, Bromus catharticus* and *Bromus berteroanus*), it is important to mention that they have not been archaeologically identified outside central and

Southern Chile. According to their “natural” distribution, these species could be found in a broader geographical zone than just central and Southern Chile (Rodriguez *et al.* 2018), except from *Bromus mango*, considered today extinct. According to historical records, these plants were collected and cultivated by Mapuche groups, and its grains were used to make bread (Lehnebach *et al*. 2008). In terms of taxa, Southern Chile and the Central mediterranean zone share most of the cultivated taxa archaeologically identified, except for gourd (*Lagenaria* spp.) and lima bean (*Phaseolus lunatus* L.). This last species was usually recovered in Late Ceramic contexts of Central Chile related to the Inca presence (Planella et al. 2014). Therefore, the absence of *Phaseolus lunatus* in Southern Chile it is not surprising since the Inca expansion was allegedly stopped by the native *Reche-Mapuche* population.

For the Historic Period, archaeobotanical evidence is scarce. Evidence recovered from “Casa-Fuerte Santa Sylvia” site (1555 cal. CE, located in the cordillera area) indicates the presence of maize and Hispanic crops along with *pehuen* (*piñon* or pinenuts of *Araucania araucana*) and charred stalks of mountain bamboo, *Chusquea spp*. (Rossen 2011). Also, a sample of *Z. mays* from the site was dated to 1464-1628 cal. CE (Roa et al. 2018). Although considering two sigma range, the date might be representative from the Late Ceramic Period, the material contexts show both a Hispanic and Indigenous input (Mera,Reyes and Vásquez 2007). More recently, *Triricum* sp. was registered in the Historic Period layers of Cueva de Los Catalanes (Roa Solís *et al.* 2024), indicating an early post contact context (16^{th}-17^{th} centuries, see chapter 8 for details of Cueva de los Catalanes).

An important aspect to highlight is that cultivated plants are usually recovered in association with wild edible plant seeds, nuts, and fruits. Although we cannot discard that some of these seeds might have entered the archaeobotanical record by chance (especially seeds or fruits from woody plants entering along with firewood), their recurrence in the different sites across different periods is indicative of its economical use.

The situation of camelid domestication in Southern Chile is not clear, and from a zooarchaeological perspective based on osteological evidence it is not possible to distinguish among wild guanaco (*Lama guanaeicoe*), *aguachado* or tamed animals, and domesticated llamas (*Lama glama*, Neün, Le *et al.* 2023). Identification based on animal fibres has been proposed as a feasible approach to differentiate between domesticated and wild camelids (Benavente *et al.* 1993), but animal fibre is not commonly preserved in the archaeological record of Southern Chile (Sánchez, Quiroz & Massone 2004). The Historic record suggests that at the time of the European arrival native populations kept domesticated camelids as far as Southern Chile (figure 5), and as described in the following chapter five, these animals were called *hueques* or *chillihueques* by the native people, and *oveja de la tierra* by the Spaniard (translated as ram or sheep of the land in English). The earliest mention of these *chilihueques* was written by Pedro de Valdivia himself in 1550 CE just after crossing the Biobio River, and the southernmost reference correspond to the Chiloé island, from an expedition in 1558 (Benavente 1985).



Figure 5 : Chilihueque or re-hueques from Southern Chile. Image from Journael ende historis verhael van de Reyse gedaen bij Costen de Straet Le Maire, naer de Custen van Chili, onder het beleyt van den Heer Generael Henrick Brouwer, inden Jare 1643 voorgevallen, Amsterdan, Broer Jansz, 1646. (Digital resource available from www.memoriachilena.cl)

Many of these descriptions homologated the *chilihueques* with the domestic llama from Peru, and over the years, different authors have discussed the taxonomy of these camelids. One of the arguments used in favour of *chillihueques* representing domestic animals is the linguistic one. According to Molina (1788), *hueque* was the term used by the *Reche* people to call their camelids, but later it changes into *rehueque* or *chiliweke* meaning the original or real *hueque (re* meaning the real or the original in *Mapudungun*), to differentiate it from the spanish *hueque,* the castillian sheeps *(carnero* or *ovejas*). Diego de Rosales (1877), a missionary who was fluent in the native *Mapudungun,* mentions that *chilihueque* refers to a domestic camelid in

contraposition of the wild guanaco, known as *luan*. While some scholars considered the *chilihueque* the southern equivalent of llamas, Molina even proposed that it was a different species from the other four known South American camelids (guanaco, vicuña, alpaca and llama) and denominated it the *Camellus Araucanus* (1788).

In archaeological terms, the more recent evidence supports several domestication events between the 4050 BCE and 50 CE (Yacobacico 2021), and paleogenetics and morphometric studies indicate high hybridizations of domestic forms, especially after the Spanish conquest (Díaz-Maroto *et al.* 2021, Neün, Le *et al.* 2023). In Chile, there is direct evidence of camelid domestication only in the Northen area (17°-26°S) between the 3000 – 1600 cal. BCE (Santoro *et al.* 2016), and until few decades ago, the presence of domestic camelids in other areas was associated with the Inca expansion or Inca influence. The more recent evidence indicates that domestic camelids of a small variety were introduced in the semi-arid north and central zone of Chile during the Late Intermediate Period (26°-33°S, from around the 1000 CE to 1400 CE), so before the Inca expansion usually dated to the 1450 CE (López *et al*. 2012, Soto 2018).

Guanacos had a much more extended and continuous distribution in the past than nowadays, and until the mid-19th century they were common in the central areas of Chile (Bonavia 2008). Although wild camelids or guanacos remains (*Lama guanicoe*) are usually found in several pre-Hispanic sites in Southern Chile, and from the 1000 CE they become much more ubiquitous and relevant in the archaeological record. Around this time, camelids were taken in boats to

oceanic islands, such as Mocha Island (38°21′S 73°54′W) and Santa María Island (37°03′S 73°31′W), where big mammals are not naturally found indicating taming practices at least (Sánchez, Quiroz & Becker 1994). Mocha Island is the most well documented case: the only DNA and morphometric data comes from this Island (Gasco & Campbell 2018, Westbury *et al.* 2016), and altogether they indicate nondomestic camelids. Although the DNA sample is small (only three individuals), it shows that the island camelids were close to the southern camelids, contesting the initial belief that Southern Chile camelid were transported from northern areas (Bonavia 2008).

The available taxon dates and isotopic data of camelids come from Mocha Island and Cueva de los Catalanes (see details in appendix A, table and figure 1). Most of them are concentrated between the 1200- 1400 CE, which is not surprising since Historical or post contact archaeology is underdeveloped. At the moment there are no post 16th century camelid's dates, which is coherent with the disappearance of this animals around the 18th century. The isotopic data show that these animals had a C3 plant based diet (Campbell *et al*. 2020).

The only direct archaeological evidence of domestic camelids comes from textile fragments recuperated in the burial contexts from the Araucanía Region. Alpaca fibres (*Lama pacos*) were identified in the Villa JMC-1 site (Mera & Munita 2021), and llama fibres (*Lama glama*) were identified in Alboyanco (Navarro & Aldunate 2002). According to the written sources, the chilihueques were appreciated because of their wool, but also as prestige items, they were used in ceremonies as sacrifices, and they were really valuable as part of marriage exchanges.

In relation to their number, the written testimonies mention that they were few of them but very much appreciated, according to Gonzales de Nájera “There are few of these sheep, so they do not have them in herds: they are raised with regale” (“*críanse con regalo”* 1889, P. 30). One of the few references with a specific number comes from Vidal Gormaz who mentions that each person had between 4 and 6 sheep, and the chiefs or caciques had between 12-15 (“*tienen a seis é cuatro ovejas cada indio é los casiques a 12 é 15”,* 1879, p. 516). In these testimonies it is also mentioned that there were no corrals or similar structures, and according to Rosales they kept the animals insides their houses (“*solamente los crían los indios con grande regalo por la lana, y miran mucho por ellos, guardándolos dentro de sus casas”* 1877, p. 324*).* Apparently, the group always follows the “alpha male”, so if they tied or kept the male near the house, the other will stay close by. There is no mention of reins meaning also no physical evidence or traces in the teeth that could be examined in zooarcheological terms. In order to tie and guide the animals, they used to perforate one of the ears to pass through a string or rope (Palermo 1986), which will not leave any permanent evidence in the bones. If there were other implements related to the management of these animals, they have not been identified in the archaeological record.

Considering the information contained in these testimonies, in archaeological terms it will be difficult to find material evidence of camelid management. There is no mention of corrals, so it might be difficult to identify concentrated dung deposits; no evident bone or teeth wear patterns associated to reins can be expected, and also no artifacts associated to herd management, since

apparently, they were kept in low numbers rather than proper herds. Altogether, the current evidence suggests that there was no local domestication of camelids and neither pre-Hispanic pastoral lifestyle south of the Mendoza Province (34°S), but there is evidence of farming and animal management as far as Southern Chile (Abbona *et al*. 2020).

Until the 17th century, the *chillihueques* were mentioned in written resources, but they disappear during the 18th century. One of the last references was written by the Abate Diego de Molina in 1776, but the last testimonies with a clear geographic location were registered during the 17th century: Mocha Island in 1686, Cautín and Imperial rivers in 1629, and Osorno plains in 1648 (Benavente 1985, Bonavia 2008, Palermo 1986). The introduction of old-world cattle had an impact not only economical terms for the *Reche-Mapuche* people, but in ecological terms it is believed that old world taxa introduced a series of diseases that affected the *chilihueques.* There are records of scabies affecting Santiago and Peru in the 16th century which might have affected the *chilihueques* (Palermos 1986, p. 75), considered today extincted (Goicovich 2018).

For a comparative perspective it is worth considering that, 20 years ago the discussion about crops and cultivated plants in Southern Chile was in a similar situation to todays domesticated animals' discussion. For several years it was assumed that there was poor organic preservation in Southern Chile, and that it was difficult to obtain direct evidence of plants unless there were exceptional preservation conditions (like the ones registered at Monteverde-II site). But once appropriate methodologies started to be applied, the panorama changed.

In the semi-arid north (26°-33°S) as well as in central Chile (33°-38°S), the presence of domestic camelids before the Inca expansion was only registered after the implementation of focused zooarchaeological analysis aiming to identify domesticated camelids (López *et al.* 2012, Soto 2018). Previous efforts to study animal camelid domestication have been focused on other Andean areas and Southern Chile samples have not been integrated systematically (Abbona *et al.* 2020, Westbury *et al.* 2016). Since no investigation program has addresses the existence of domestic camelids in Southern Chile, the panorama could change in few years once a directed systematic zooarchaeological investigation is conducted.

In relation to other domesticated animals, it is relevant to address the controversial presence of Polynesian chicken in Southern Chile. Previous studies have reported the existence of pre-Hispanic chickens dated between 1300-1450 cal. CE (Storey *et al.* 2013), but subsequent investigation of their genetic sequences indicates that they descended from Eurasian chicken lineages associated with early European colonialism rather than ancient Polynesian chickens (Gongora *et al*. 2008). The study of Gongora and collaborators (2008) highlights the importance of the estimated marine reservoir effect and marine derived diet of chicken, as minor shifts in the assumed chicken diet can shift the calibrated date into the post contact period. A more recent revaluation of the El Arenal-1 site, where the allegedly chicken bones were identified (for more details of the site see chapter nine), indicates no presence of chicken bones (Buhring *et al.* 2023). Considering this evidence

and the early records (chapter five), seems that chickens may have spread very widely during the 16th century.

Altogether, the evidence for Southern Chile shows presence of crops and agricultural practices at least 500 years before the Spanish arrival, and evidence of crop consumption can be found as far as the septentrional Patagonia. In relation to the camelid domestication, there is no evidence supporting a local domestication process, but there is evidence of camelid management. The studies from more northern areas show that camelid domestication was a nonlinear process, and there were more camelid varieties than the ones known today, including some wild ancestors today extinct (Díaz-Maroto *et al.* 2021, Soto 2018). The limited current DNA and osteometric evidence indicates presence of "tamed" guanacos (*L. guaneicoe*), and the only evidence of domesticated camelids comes from textile fibre analysis. Even though textiles could have arrived by exchange to Southern Chile, it is also possible that tamed guanacos coexisted with domestic camelids.

4.3 Archaeological data in relation to pre-Hispanic landscape modification

Earthen mounds and platforms dated to the Late Ceramic and Historic Periods are considered the most evident archaeological form of public architecture and landscape modification of Southern Chile (Campbell & Pfeiffer 2017, Dillehay *et al.* 2007). Although landscape modification is evident from the Late Ceramic

Period onwards, the topic has mainly been approached from ritual, social and symbolic perspectives (Urbina, Adán & Alvarado 2023).

Archaeological evidence of agricultural terraces (PU-118 and PU-127) and channelized fields (PU-98) has been reported in the Puren-Lumaco Valley along with charred macro remains of maize, quinoa, and other grains (Dillehay 2010). A radiocarbon date (1220-1420 cal. CE) suggests that these agricultural fields correspond to the Late Ceramic Period. In the coast, raised agricultural fields have been reported in the delta of the Paicaví River. A single radiocarbon date indicates a Late Ceramic Chronology (1480 cal. CE), but it has been interpretated as a probably Early Historic context (Dillehay et al. 2020). Further south, in the mouth of the Budi Lake (the delta of the Imperial River), raised fields were reported. A radiocarbon date obtained from the proto-palaeosol strata of one of the fields (1210-1320 cal. CE) also indicates a Late Ceramic chronology (Dillehay *et al*. 2007).

Despite this evidence, part of the archaeological community is sceptical about large-scale agricultural infrastructure, and landscape modification has not been discussed in terms of its environmental significance. Although nowadays there is enough archaeobotanical evidence to support pre-Hispanic agriculture in Southern Chile (Roa *et al.* 2018), there is no consensus about its scale.

According to the first written records the native populations of Southern Chile practiced slash and burn agriculture by 1550 CE (Aldunate 1989, Dillehay 1990). Though there is no direct archaeological evidence, it has been usually assumed that pre-Hispanic populations also developed slash and burn agriculture/horticulture (Abarzúa 2009, Armesto *et al.* 2010).

Even though in paleoenvironmental terms is difficult to distinguish between anthropic and natural fires, analysis from sediment columns on Mocha Island and the Purén-Lumaco valley have related charcoal peaks with forest clearance probably conducted by pre-Hispanic groups. Pollen analysis conducted on both areas also correlates some vegetation changes (such as rises in successional bushes, open canopy species, and grasses) to an anthropic disturbance of landscape (Abarzúa 2009, LeQuesne, Villagrán & Villa 1999).

Since there is not enough data to compare among the different pre-Hispanic Periods, is difficult to estimate if because of agriculture and animal management during the Ceramic Period, the demand of open land increased. From an ethological perspective, wild and domestic camelids live most of the year in open habitats where grasses are available for pasture (Franklin & Johnson 1994). Ethnography indicates that it was common among pre-Hispanic indigenous groups of the Americas to artificially maintained grassland for llamas (Tomka 1992). Nevertheless, it also known that hunter gatherer groups used fire to facilitate hunting (González *et al.* 2020, Martinic 1995), so it cannot be a priori assumed that groups from the Later Periods burned more extensively or frequently than the groups from earlier periods.

Chapter 5: Southern Chile landscape descriptions (16th - 20th centuries)

This chapter presents a revision of historical and environmental sources in order to obtain an image of the landscape and the forest extension of Southern Chile by the time of the Spanish conqueror's arrival and its transformations through time. The revision only considered already published sources, that were selected with the intention of exploring the origins of the narrative of the pristine forest in Southern Chile that still affects the archaeological and environmental perspectives in relation to forest landscapes. Most of the sources were consulted in the original written language (Spanish, English and Dutch), and while the English sources were copied textually, an own free translation is given for the ones written originally in Spanish and Dutch along with the corresponding textually copied citations.

In chronological terms, the information has been divided into three major time sections: the arrival of the Spaniards conquerors until the abandonment of the city's south of the Biobío River (1550-1604 CE), the free Indian country (1604-1825 CE), and the Republican Period (1825 CE- present-day).

5.1 Chronicles and early descriptions of Southern Chile (1550-1604 CE)

The earliest written testimony that describes Southern Chile is the compilation of letters from Pedro de Valdivia, who was the first royal governor of Chile. Valdivia arrived from Perú in what today correspond to Chilean territory in 1549

and was killed few years later in Southern Chile (1553 CE). Although part of the Chilean territory had been previously explored by Diego de Almagro, Valdivia was the first Spaniard to lead the conquest army south of the Biobío River (1550 CE). In a letter written in 1550 CE addressed to the Spanish Royal court, Valdivia describes the territory south of the Biobío River as a fructiferous land with an abundance of cultivated lands, wood, and anything else that might be needed in order to be inhabited, in its own words: "*Informa así mismo de la buena tierra qu'es ésta, de buen temple, fructífera e abundosa e de sementeras e de mucha madera e todo lo demás qu'es menester e se requiere para ser poblada e perpetuada de nosotros*" (Valdivia 1970, p. 180).

In another letter written in the same year but addressed to King Carlos V of Spain, Valdivia mentioned the fertile and gentle characteristics of the territory and commented how densely inhabited it was. According to the letter, there was little chance of wild animals inhabiting the land (such as wolves or foxes), and if there were any, they were likely to breed between houses and the cultivation lands of the indigenous people because there was no other land left:

"*es más poblada que la Nueva España, muy sana, fertilísima e apacible, (…) es muy llana, y lo que no lo es, unas costezuelas apacibles; de mucha madera y muy linda. Es tan poblada, que no hay animal salvaje entre la gente, de raposo, lobo y otras sabandijas de esta calidad, y si las hay, les conviene ser domésticas, porque no tienen a donde criar a sus hijos si no es entre las casas de los indios y sus sementeras"* (1970, p.156-157).

After the foundation of La Concepción (1550 CE) and La Imperial (1551 CE), Valdivia sent troops to keep exploring further south. In a later letter to the king,

written in 1551, Valdivia indicated a large population inhabiting nearby the Valdivia River (39°81' S). With a rhetoric narrative, he stated about the land: "it is a whole town and a cultivation field and a gold mine, and if the houses are not placed on top of each other, they cannot fit in it more than it has, prosperous with cattle" ("*es toda un pueblo e una simentera y una mina de oro, y si las casas no se ponen unas sobre otras, no pueden caber en ella más de las que tiene, próspera de ganado,* …") (1970, p.171)

According to these early letters, the indigenous groups cultivated maize ("*maís", Zea mays*), potatoes (*papas, Solanum tuberosum*), quinoa ("*quinua", Chenopodium quinoa*), *madi* (*"mare", Madia sativa*), chili peppers *(ají*, *Capsicum sp*.) and beans ("*frisoles", Phaseolus vulgaris*). Also, they kept livestock which presumably corresponds to domesticated/tamed woolly camelids since they are compared to the ones from Perú "*ganado como lo del Perú, con una lana que le arrastra por el suelo"* (1970, p. 171). It is also mentioned that the people wear clothes made of wool ("*vestidos de lana*", 1970, p. 172).

The first Chronicle written in Chile is *Crónica y relación copiosa y verdadera de los Reynos de Chile*, by Gerónimo de Bibar (also referred as Jerónimo de Vivar). It was completed in 1558 and covers until the five years after Pedro de Valdivia was killed. The author was a soldier who supposedly accompanied Pedro de Valdivia in the military campaigns to conquest the Chilean territory. Although Bibar´s chronicle gives more details than Valdivia's letters, in both authors there is an idealised representation of the landscape (Cordero 1999). Narrative analysis of these early descriptions has highlighted the emphasis of

a densely inhabited territory with fertile lands where crops were abundant, which corresponds to the “abundance discourse”, common in the early descriptions of the Americas (Ortega 1992). In the case of Chile, these positive descriptions were intended to eliminate previous infamous perceptions of the territory expressed by the first incursion led by Diego de Almagro (Pérez 2018). The deliberate descriptions of *a* fertile territory, abundant in cultivation fields, wood, gold, and people, intended to present Chile as a valuable territory with available agricultural land and people to force to work on the mines and on the land.

In Bibar´s own words “*Hay del rio de Itata hasta el Río de Toltén, que está a 8 leguas de la ciudad Imperial, 60 leguas, y todo este termino está muy poblada de gente muy belicosa*” (1966, p. 152), meaning that the 60 leagues between the Itata and the Toltén River were well populated by very bellicose people.

After the city of Valdivia was founded (1552 CE), Bibar describes that seven leagues away from the mentioned city, they encountered a well-populated territory without any forest (likely to correspond to the plains near Osorno: *Llanos de Osorno* and *Llanos de La Union*). There where were no trees unless they were planted by hand, and it was a fertile land of maize, beans, and potatoes:

“Andadas siete leguas de esta ciudad, dimos en un rio muy hondable y caudaloso y en tierra muy poblada y sin monte porque en las siete leguas cesa la montaña. Esta tierra que he dicho que esta sin monte no hay árbol si no es puesto a mano. Es tres leguas de latitud y diez o doce de longitud. Este

compás que está sin monte es tierra fertil de maíz y frisoles y de papas" (Bibar 1966, p. 166-167).

Bibar´s chronicle gives more details in relation to the plants cultivated in Southern Chile by the indigenous people, who were described as great tillers and cultivated very well the land *("son muy grandes labradores y cultivan muy bien la tierra*"1966, p. 153). In addition to the plants already mentioned in Valdivia's Letters (maize, quinoa, beans, potato, *madi,* chili peppers), Bibar informs about squash (*zapallo*, *Cucurbita maxima*) and an "oat like" grass ("*es como avena"* (1966, p. 156). The last one presumably corresponds to *Bromus*, since three species of this genera were reported to be consumed until the 19th century: *lanco* (*Bromus catharticus), trüka* (*Bromus berteroanus), and mangu (Bromus mango*) (Mösbach, de 1992, Roa 2016). The chronicle also gives accounts of the use and consumption of native plants such as strawberry *(frutilla, Fragaria chiloensis (L.) Mill,* p.153*),* as well as the consumption of tree nuts and fruits such as pine nuts *(piñones, Araucaria araucana,* p. 153*),* fruits like hazelnuts *(fruto como avellanas, Gevuina avellana* Molina, p.153*),* and a yellow fruit similar to a nut *(fruta a manera de nueces).* The description of this last unnamed fruit corresponds to the *qeule, queule* or *keule* tree *(Gomortega keule* (Molina) Baill., p. 152*),* which is mentioned to be only found in tree leagues around La Concepción city. The other trees, a *pine like* (most probably to be *Araucaria araucana)* and the hazelnut like tree *(*most probably referring to *Gevuina avellana)* are mentioned to be frequent south of the Biobío River. In relation to the animals, Bibar mentioned the existence of livestock *(ganado)* and tame sheep *(oveja mansa),* and that the people wear clothes made of wool.

Is also interesting how the chronicle depicts, by contrast, the people inhabiting the cordillera area, who don't cultivate the land and live on the hunt of animals such as guanaco *(Lama guanicoe)* and other animals.

In relation to woods and forest descriptions, Pedro de Valdivia mentions that south of the Biobío River there is plenty of wood *(de mucha madera).* Bibar indicated that woods were more abundant in the cordillera areas or sometimes leagues away from the main valley or cities. When mentioning the Imperial River valley, he informs that the land was well populated, hilly but in parts smooth and has woods one and a half leagues away from where wood for houses is brought *("Es tierra doblada, en partes llana; es tierra muy poblada; tiene el monte legua y media de donde se trae la madera para las casas"* 1960, p. 150*).* South of the Toltén River, Bibar described woods with trees such as oaks (*robles, Nothofagus sp*.), myrtle *(arrayan, Luma apiculata* (DC.) Burret) and hazel (*avellano*, *Gevuina avellana*) along with large amounts of big canes (*Chusquea sp*.). These woods are mentioned to be thin in some parts, and in other very thick *("Desde el río Tolten es montuosa, y estos árboles son robles y arrayanes y de ellos avellanos que tengo dicho. Hay gran cantidad de cañas macizas. Estos montes en alguna parte son ralos y en otras muy espesos"* 1966, p. 158).

Other testimonies written by soldiers who travelled to Southern Chile before 1600, depicted a similar landscape, although they were written without showing a specific interest in the territory and the environment. The Chronicles of Mariño de Lovera (who lived in Chile between 1551-1562), Gongora de Marmolejo (who lived in Chile between 1549-1575), and the epic poem written by Alonso

de Ercilla (who visit Chile between 1557 and 1559) share similarities in their descriptions. In fact, posterior analyses have suggested that the similitudes in these later publications indicate the use of Valdivia's letters and Bibar's chronicle as a secondary source, in order to fill up gaps of information by these later authors (Cordero 1999, Pérez 2018). All of these early eyewitnesses' testimonies also shared an occidental and Christian perspective and a bias towards the justification of the Spanish conquest. Even though these testimonies are not objective representations of the territory, Environmental history studies based on them propose that at the time of the Spanish conqueror's arrival, Southern Chile was not completely covered by a dense forests (Bengoa 2003, Camus 2002, 2005, Otero 2006). On the contrary, from these testimonies is possible to estimate that Southern Chile presented dense inhabited areas with cultivation and pasture fields (mostly around river valleys), as well as forests nearby these settlements where wood and other resources were obtained. According to Camus (2006) and Bengoa (2004), the landscape of Southern Chile in 1550 should be understood as an association of clear lands and woods.

The decay of the indigenous population and the war against the conqueror also caused changes in the indigenous settlements. Since most of the Spanish cities were founded in the fertile valleys previously occupied by the *Reche-Mapuche,* part of the remaining population left the once densely populated valleys (Adán 2014). In a letter dated to 1593 CE addressed to the King of Spain, the Spanish Governor Martín García de Loyola described a rather different panorama than the one observed 40 years before by Pedro de Valdivia

and Gerónimo de Bibar. García de Loyola argues that the indigenous population was able to resist the continuous Spanish military offenses because of "the inexpugnability of the rough and woody place of its habitation and by not having for living a congregation of towns but different and wild households where is necessary to divide and clear the fields to look for them" ("*la inexpugnabilidad del aspero y montuoso sitio de su habitacion y no tener para su morada congregacion de pueblos sino caserias distintas y silvestres donde para buscarlos es necesario dividir y desmontar el campo*" García de Loyola, 1593, cited in Boccara, 1999, p. 428). Although what García de Loyola describes might be an exaggeration in order to justify the difficulties of the conquest war, part of the decimated population left the valleys and moved to less fertile areas but protected by trees. This more dispersed habitation pattern in the forests responded not only to the decay of the population but also to tactical reasons, as forests offered an advantage against military attacks from the Spanish army. The indigenous warriors used the coverage and protection of trees to ambush the Spaniard's troops. The Spaniards rapidly learned that they did not have much chance of defeating the indigenous warriors if they were in woody locations (Camus 2005). Bibar mentioned that best defense for the Spaniars was to fight in clear/smooth lands (*"ya es notorio que la fortaleza de los españoles para con los indios es en lo llano gran defensa*" 1966, p. 87). The woods were used as a tactical advantage in favour of the native population. Even in the epic poem "La Araucana" written by Ercilla (first published in 1569), the woods are also depicted as the favourable scenario for the indigenous warriors: "Tangled, rough, and harsh wood:/ Here fight best the Araucanians"

(“*Espesos montes asperos y duros: / mejor pelean aquí los araucanos*” Ercilla 1574, p. 83).

It is relevant to highlight that the most common term to refer to the forest is *monte*, which in Spanish todays refers generally to a hill, but it was used in these written sources to indicate a vegetal formation dominated by shrubs and trees where the transit is difficult (Villalobos 2018, p. 190). Monte is still used among Southern Chile inhabitants to refer to an unmanaged and sometimes inaccessible forested areas (Di Giminiani 2016). The contrast between the *monte* and the open fields and proper settlements was established early on as a mirror of the opposition between civilization and wilderness/ barbarism.

After the indigenous victory in the Curalaba Battle (1558 CE, Lumaco River valley), most of the Spaniards and their indigenous allies had to move out of Southern Chile (Sauer 2015, p. 145). By 1604, all the forts and Spanish settlements located between the Biobío and the Toltén river were abandoned (Téllez, Silva & González 2020).

One of the testimonies depicting the late years of the Spanish occupation of Southern Chile is *Reparo y desengaño de la Guerra del Reino de Chile*, written by the Spanish soldier Alonso Gonzales de Nájera. The author lived approximately five years in Southern Chile (1601-1605 CE) and finished writing his testimony in 1612 CE, but like many other manuscripts of those centuries, it was published much later in the 19th century. Although the central theme of this chronicle is the conquest war, it was not written using a heroic narrative. The author gives detailed observations about the indigenous culture, their customs and the surroundings. In relation to the indigenous populations, Nájera

described a disperse habitation pattern similar to the one informed by Governor García de Loyola. Najera states that “the Indians do not have cities, towns or places for their habitation, nor forts, nor any other kind of fortress outside of the great swamp of Puren, which is by nature and helped by them by art” (“*no tienen los indios ciudades, villas o lugares para su habitación, ni fuertes, ni otro género de fortaleza fuera de la gran Ciénaga de Puren, que lo es por naturaleza y ayudada dellos por arte”* González de Najera 1889, p. 48). His testimony is one of the few giving an explicit account of landscape modification: a great “natural” fortress aided or helped by the art/craft of the native population.

In relation to social drinking and celebrations, Gonzales de Nájera describes the existence of woods and fields used with this particular purpose of social gatherings. These woods were used to meet and drink, and according to his testimony “seem made or bred for this purpose, with little circuit and very tall and diformed trees: places that are commonly called by our people *bebederos*” (*“son unos bosques que parecen hechos o criados para tal efecto, de poco circuito y de altísimos y diformes árboles: lugares a que comunmente llaman los nuestros bebederos”* 1889, p. 43). He also gave good descriptions concerning strawberry cultivation, not only indicating the different shapes, sizes and colours depending on if they were grown in gardens or the country, but also, he mentions how they were planted and transported to places.

Is also interesting that although there were no early estimations of the number of domestic/tamed camelids in Southern Chile, Nájera mentioned “There are few of these sheep, so they do not have them in herds: they are raised with

regale: the Indians use their wool to dress" ("*Hay pocos de estos carneros, por lo que no los tienen a manadas: críanse con regalo: aprovechándose los indios de sus lanas para vestirse*" 1889, p. 30).

Najera also mentions not only the fast and successful adoption of the horse but also the adoption of wheat and barley. Since one of the conqueror's strategies was to burn the indigenous cultivation fields, European crops were adopted early on by the *Reche-Mapuche* communities because they took less time to be ready for harvest ("*eran de mucha más temprana cogida"* 1889, p. 176) and they required less care than corn ("*trigos y cebadas no requerían tanto regalo como sus maíces"* 1889, p.176).

In relation to the landscape, Najera describes the existence of forests as well as open fields. In his own words "Between these mountains and valleys there are still spaces of flat lands, in some parts more extended than in others, although they are surrounded by mountainous hills, very useful for plowing, and other bare hills, very fertile for the same" (*"Entre estos montes y valles no deja de haber espacios de tierras llanas, en unas partes más extendidas que en otras, aunque cercadas de montuosos cerros, utilísimas a labranzas, y otros pelados collados muy fértiles para el mismo"* 1889, p. 8).

Although the population drop had clear effects on the Southern Chile landscape, 50 years is still a short period of time to estimate the environmental effects of the Spanish conquest. What these early testimonies describe was far from being a pristine landscape. On the contrary, by 1550 CE the Southern Chile original population had an active role modelling its surroundings.

5.2 The free Indian country (1604 - 1825 CE)

An official document signed in 1612 CE by the Spanish crown designated the Bio-Bio River as the official frontier between the Hispanic and Indigenous territory (Téllez *et al.* 2011). Although a frontier was established, interactions and trade between both sides were frequent (Sauer 2015, p. 147). Jesuit missions were founded south of the Biobío, and they played a central role as mediators between both sides (Goicovich 2007). More than a decade later, after the "Parlamento de Quilin" (1641 CE), the territory south of the Biobio was recognized as a free state and the indigenous people as independent and autonomous groups (Bengoa 2004, p. 19). The Toltén River acted as a southern frontier of this "free Indian State" since south from it, the city of Valdivia was refunded and repopulated in 1645 CE and Osorno in 1796 CE.

During those years, the first compilations intending to give detailed descriptions of the Chilean territory were written by two Jesuit priests. The *Histórica relación del Reyno de Chile* by Alonso de Ovalle *was* published in 1646, and the *Historia jeneral de el Reyno* de Chile by Diego de Rosales initially intended to be printed in 1655 CE (finally published in 1877 CE). De Ovalle was born in Chile (1601 CE) but moved to Rome in 1640 CE, from where he wrote and published his book. He compilated most of the sources available at that time, and he even used some unpublished manuscripts written by Rosales to obtain information about Chile (Mackena 1877).

Although Rosales also used some secondary sources, an important part of his descriptions resulted from the 30 years of missionary work in Southern Chile, where he first moved in 1628. Rosales was fluent in the indigenous languages, and his book contains ethnobotanical descriptions of over one hundred plants (Prieto 2011). Until today, Rosales's descriptions are considered one of the best sources of early ethnobotanical knowledge of Southern Chile.

In addition to the cultivated plants described previously on the chronicles, de Ovalle and Rosales's work give detail about the use of different native plants with medicinal properties, as well as the properties and or uses of trees and shrubs (especially on Rosales´s work). Special attention is given to native edible plants such as strawberry *(frutilla, Fragaria chiloensis*), Chilean guava berry or strawberry myrtle (*murtilla, Ugni molinae* Turcz), *queule (Gomortega keule*), "pine nuts" (*piñones, Araucaria araucana*), and hazelnuts *("abellanas", Gevuina avellana*). Rosales described that in Villarica "their fields abound with a lot of strawberries, a lot of berries and potatoes, which without sowing them the fields naturally yield; has hazelnuts in abundance and enjoys the gift of pine nuts "("*abundan de mucha frutilla sus campos, de mucha murtilla y papas, que sin sembrarlas las dan naturalmente sus campañas; tiene abellanas en abundancia y goza del regalo de los piñones*" Rosales 1877, p. 468). De Ovalle mentions that he saw "complete leagues of strawberry fields that growth of itself in the land,(…)they grow as big as pears, and although commonly they are red, there are also, whites and yellow ones" ("*y he visto leguas enteras de frutillares que nacen de los suyo en el campo,…, porque crecen de tan grandes como peras, y aunque de ordinario son rojas, las hay también, en la*

Concepción, blancas y amarillas" de Ovalle 1969, p. 24). Similarly, Rosales describes fields of abundant strawberries and berries that existed near the city of Valdivia city, as well as mountains covered by hazelnut trees (*avellanos)* near Osorno. He also mentions that the Queule River (south of the Toltén River) was named after the presence of this type of tree in its riviera (*Gomortega keule*), which according to the previous reports of Gerónimo de Bibar (1966), was only to be found around La Concepcion (north of the Biobío River).

Both authors did not discuss or mention if these trees were managed in some way. Even more, de Ovalle states that "trees, although wild, bear very tasty fruits of the earth" ("*Los árboles, aunque silvestres, llevan frutas de la tierra muy sabrosas*" 1969, p. 51). But, by contrasting these descriptions with the ecological information it is possible to infer some level of anthropic modification. The avellano tree (*G. avellana*) usually grows in the companiony of other tree species and only occasionally can form small mono-specific groups (Rodríguez, Matthei & Quezada 1983, p. 162). Therefore, seems unlikely to find a hill naturally covered by them.

Strawberries and other berries are also mentioned to grow naturally, although earlier descriptions, such as the chronicle of Gonzáles de Nájera mention they were cultivated. Recent studies have stated that the strawberry was domesticated and cultivated since pre-Hispanic times based on the existence of the different phenotypes (Finn *et al.* 2013, Hancock, Lavín & Retamales 1999). De Ovalle mentions three different colours (red, yellow, and white), and in the later *Mapudungun* compilation written by Febres (1765), there are two different native terms for strawberry: *quellghen* for the cultivated type and

llahueñ for the wild one (Pardo & Pizarro 2016, p.223). Seems likely that de Ovalle and Rosales assumed that a lot of plants grew “naturally” because they were not managed/cultivated under occidental parameters.

In relation to the domestication of camelids, both authors mention that the sheep from the earth (*ovejas de la tierra*) or *chillihueque* were not raised because of their meat. Rosales describes that they were raised because of the wool and that they are usually kept indoors due to their value as part of marriage exchanges. In his own words:

“*solamente los crían los indios con grande regalo por la lana, y miran mucho por ellos, guardándolos dentro de sus casas porque es la mejor hacienda que tienen para comprar mugeres para casarse, que es paga de mucha estimación*” (Rosales 1877, p. 324).

As well as the earlier descriptions, these authors did not mention how big was the domesticated/tamed camelid population of Southern Chile, or how many were kept by each family or domestic unit. Most authors emphasise how valuable they were, and the only record of camelids being used as working animals was mentioned by de Ovalle based on the descriptions of the Dutch expedition led by Van Speilbergen in 1615 CE. According to Speilbergen, camelids were used in Mocha Island for ploughing, although its description has been mentioned to be dubious (Campbell 2011).

In relation to the landscape, both authors reconstructed the scenery during the expeditions of Pedro de Valdivia using earlier sources as well as some personal observations. Alonso de Ovalle mentions the existence of dense forests as well

as an abundance of fertile prairies. Near the city of La Concepción, he describes "forests so thick and entire that, penetrating a little inside, it cannot be broken, and this is half a league from the city; there are inland ravines, where no man has ever set foot" (" *bosques tan espesos y enteros que, penetrando un poco adentro, no se puede romper, y esto a media legua de la ciudad; que la tierra más adentro hay quebradas, donde no ha puesto el pie hombre alguno jamás*" 1969, p. 19). In contrast, the surroundings of La Imperial are described as "not all plains and valleys nor all mountains, but a medium where both participate, nor is the woods are rough and unpalatable, but rather very easy and gentle hills, with good stalls and shelters for cattle" *("no son todo llanuras y valles ni todo montañas, sino un medio que participa de lo uno y de lo otro, ni lo montuoso es áspero y desabrido, sino unas colinas muy tratables y suaves, con buenos puestos y abrigos para ganados"* 1969, p. 209).

Similarly, in relation to the natives from La Imperial, Rosales writes: "and being their land clearer and not so populated with mountains as the cordillera, it has made them more domestic, by having the populations closer together and not having so much mountain in their land where to build forts to defend themselves and wage war ("*y al ser su tierra mas descubierta y no tan poblada de montaña como la de la cordillera, los ha hecho mas domesticos, por tener las poblaciones mas juntas y no tener tanta montaña donde hacerse fuertes para defenderse y hacer guerra*." Rosales 1877, p. 456). Although these descriptions were based on secondary sources, it is interesting how de Ovalle associated the existence of dense forests with the pristine or untouched by people, while Rosales associates it with the wilderness and undomesticated.

Rosales also observed that one of the difficulties of the Spaniard conquest and evangelization was the indigenous practice of not forming proper towns with houses next to each other. He declares that “the preachers do not find them in towns, not in cities, nor can they be united, instead they have to go from house to house, from ravine to ravine” *(“ los predicadores no los hallan en pueblos, ni en ciudades, ni los pueden juntat, sino que an de andar de casa en casa y de quebrada en quebrada”* 1877, p. 151). Quite the opposite, he describes that “everyone makes their home in the mountain to have in it covert and defence” (*“cada uno haze su casa en la montaña para tener en ella su guarida y defensa”* 1877, p. 151).

Contemporary to these two Jesuits authors, is the testimony of Francisco Núñez de Pineda y Bascuñán, a soldier born in Chile but of Spanish heritage who was taken prisoner in 1629 CE for some of the winter and spring months. Nuñez de Pineda wrote his memories years later (1673 CE) and named them *Cautiverio Feliz* which means Happy Captivity. The book was written in a testimonial style where the experiences and perceptions are central, while other aspects such as time and geographical references are vague and secondary to the narration (Massmann 2012). Even so, his testimony gives information about the daily life of the *Reche-Mapuche* of the 17th century.

During most of the narration, the author gives the impression that most households were well separated from each other (taking in some cases more than one day to reach the next neighbour). Also, he describes the existence of refuges deep in the forest used to escape from the military attacks: “this hut and others in the same way had the frontiersman in ravines and rough and

impregnable forests, where in summer and weapons rampage time they would retrieve to sleep *("Este ranchuelo y otros de la misma forma tenían los más fronterizos en quebradas y montes ásperos e inexpugables, a donde en tiempo de verano y de alboroto de armas se recogían a dormir" Núñez de Pineda y Bascuñán, 1948, pp. 199–200)*. Since the description doesn't specify how long ago they were used, the narrator could be referring to the most belligerent years of the 16th century and it is not clear if these shelters were still in use during the 17th century. Keeping in mind that descriptions from the late years of the 16th century mentioned the inexistence of towns or any household congregation, seems very relevant his observations around the Imperial River valley, where once stood La Imperial city. Núñez de Pineda mentioned: "we also discovered through those plains of such peaceful valleys many ranches founded on its banks with many crops and fruit trees" (*"Descubrimos también por aquellos llanos de tan apacible valles muchos ranchos fundados en sus orillas con muchas sementeras y árboles frutales."* 1984, p. 289). This suggests that after the Spaniards left, part of the remaining *Reche-Mapuche* Population reoccupied the fertile valleys. According to Adán (2014), the Imperial Valley was a relatively calm territory during those years, allowing the resettlement of some households and implying a dense inhabitation of the area.

During his captivity, Núñez de Pineda spent time in different households. He mentioned the existence of gardens ("*chacacras",* p. 196), which seemed to be nearby the houses, and also raised agricultural fields (*camellones*, p. 129 and 320). Although he mentioned that potatoes, beans and maize were cultivated, it is not possible to estimate the extension of the cultivation areas. Other plants

are mentioned to be consumed as well, such as chili peppers (*ají, Capsicum sp*.), quinoa (*Chenopodium quinoa*), *made (Madia sativa*), squash (*zapallo, Cucurbita maxima*), and strawberries (*frutilla*, *Fragaria chiloensis*). In relation to this last one, Núñez de Pineda states that strawberries fields were well cared for, and they were as important to the *Reche-Mapuche* as vineyards were to Spaniards since they used it for brewing chicha ("*porque de la suerte que entre nosotros se benefician las viñas, de la propia y aun con más cuidado labran ellos sus frutillares"* 1984, p. 415).

He also participated in the collection of firewood, which was usually done in the near woody surroundings of the houses. In one of those occasions, he described: "We made our bundles of firewood very quickly, because the forest offered it abundantly" ("*Hicimos nuestros haces de leña con toda brevedad, porque abundante nos la ofrecía el monte*" 1984, p. 393).

In the narration of Núñez de Pineda, the adoption of European elements into the *Reche-Mapuche* society is evident. European animals such as horses, cows, lamb, and chickens are mentioned to be common in Southern Chile. Other European fruits, such as apples, are also mentioned to be adopted for chicha preparation. The author mentions however that the indigenous living closer to the frontier adopted more elements from the Spanish people (way of dressing and meal preparations) than the ones living farther from it. Wheat and other old-world crops were not directly mentioned in his narration, but it is believed that by the 17th century traditional crops, such as maize, were less frequently used to make fermented drinks (Adán 2014).

Another of the testimonies from the period are the *Travels of Ruiz Pavón and Dombey in Peru and Chile*, by Hipólito Ruiz (1910). The author was a Spanish botanist sent by the Spanish Crown to lead a Botanical expedition of the Peruvian Viceroyalty and Chile, with the French Doctor and Botanist Joseph Dombey. Both botanists travelled around Chile between February 1772 and October 1773, and although Ruiz kept diaries, part of them were lost on a fire and many of the original descriptions of the Chilean territory and provinces were lost (taxonomic and botanical outputs of this expedition were published separated). In Southern Chile they managed to go south of the Biobío River, but most of the available landscape descriptions come from the surroundings of the City of Concepción. After crossing the Laraquete River ("*araguete*" River), Ruiz mentions:

"there are seven spacious and straight lanes of different wild trees, formed, according to the natives, by nature; but it seems impossible that nature would place the seven lanes at the same distance, giving them forty to fifty yards of equal width throughout their length of five leagues, so that there is not a plant or a shrub in those lanes except the trees that make up the rows, namely arayanes, pataguas, boldus, maytenes, peumos, tires, voguis, and other climbing and twining plants."(Ruiz 1910, p. 116-117).

The mentioned taxa include species of the Myrtaceae and Monimiaceae family, as well other taxa such as *Peumus boldus, Maytenus* sp. and *Cryptocarya alba*. Most of them are sclerophyllous taxa, and altogether they inform of open spaces (no shade tolerant taxa were mentioned). From this description, is not clear how long ago these tree lanes were formed or if they were definitely the

product of indigenous management, but the absence of European taxa could indicate so. Apple and other exotic fruit trees were planted in many of the early Spaniard settlements, and they often survived long after the settlements were abandoned as it will be mentioned and discussed further ahead in this chapter.

In socioeconomical terms, if by the 16th century the *Reche-Mapuche* had a more agricultural-oriented economy, during the following centuries they became a mainly husbandry-oriented economy. By the 18th century, the main economic activity was exotic livestock husbandry (ovine, bovine, and equine) and the commerce of the textiles made from them. According to Boccara (1999), during the first 50 years of the 17th century, the *Reche-Mapuche* were still in the initial phase of livestock keeping, but by the end of this century, the economic focus on husbandry was consolidated and maintained until the 19th century. Also, from the 18th century, the term Mapuche was used by themselves not only to refer to the groups living in Southern Chile but also to the ones in the Argentinian Pampas (plains). Although communication and transit between both slopes of the cordillera were frequent since pre-Hispanic times, the Argentinian pampas provided good and extensive pasture fields for livestock foraging, which increased the presence and influence of the Mapuche during this century. The Mapuche influence was so, that Mapudungun, also referred to as “araucanian tongue” became the lingua franca of the Argentine pampas (Crosby 1972, p.82).

In terms of landscape reconstruction, little is known about this period. Some environmental history studies tend to consider these years as a period of environmental alteration caused by the introduction of cattle and exotic plant

species (Torrejón & Cisternas 2002, 2003), but also by timber and wood fuel extraction (Camus 2005). Hipolito Ruiz mentions that in Fort Nacimiento (situated at the foot of the cordillera) “by the royal order they were cutting Chilean pines for masts and the interiors of boats” (1910, p. 136), meaning the extraction of *Araucaria araucana*. After the re-foundation of the city’s south of the Toltén River (Valdivia in 1645 CE, and Osorno in 1796 CE), the Spaniards created sawmills to exploit timber. The exploitation was focused on larch (alerce, *Fitzroya cupressoides* (Molina) I.M. Johnst.), that was later sent to other regions of Chile, and even to Peru. Shipyards were also created in Valdivia and Chiloé, and eventually, other parts of the Reloncaví Gulf and Continental Chiloé were exploited as well.

More interdisciplinary studies considered the drop of the native population as one of the most relevant factors (Camus & Solari 2008, Camus 2005, Heilmayr *et al.* 2016, Lara *et al.* 2012, Otero 2006). According to these estimations, the abandonment of cultivation fields and the dispersed inhabitation of the territory lead to a regrowth of native forest during those almost 300 years. In 1915, the first Chilean Inspector General of Forests, Hunting and Fishing, Federico Albert, proposed that the maximum extension of the Chilean forests was reached by the end of the Colonial Period and the beginning of the Chilean Republic (early 19th century). He estimated that by that time the entire country had between 24 and 29 million hectares of native forest, and by the beginning of the 20th century approximately 15 million hectares of forest remained (Heilmayr *et al*. 2016).

The emancipation of Chile from the Spanish Crown has been settled in 1810. The last territory occupied by the Spaniards was Chiloé, an archipelago incorporated into Chilean sovereignty in 1826 (although the Spanish crown officially recognized the Independence of Chile just in 1844). The first attempts from the Chilean State to take control over the “The free-Indian country” were initiated in 1825 with the “Parlamento de Tapihue” (Téllez *et al.* 2011). After the negotiations, Chile designated and placed a frontier army north of the Biobío River (Sauer 2015, p.165), marking the antecedent of the “Pacificación de la Araucanía” military campaign (1850s-1882).

5.3 Republican Period (1825 CE- present-day)

From 1825 CE onwards, different *parlamentos* (parleys or peace treaties) were held between the Mapuche and the Chilean Army (as representatives of the Chilean State). Although the Biobío River was still functioning as a frontier, during the first half of the 19th century a considerable mass of Chileans moved south of the Biobío (mostly peasants or *campesinos* whom initially moved alongside the coast). Bengoa (1996) estimates that by 1860 CE, most of the territory between the Biobio and Malleco Rivers was either bought or occupied by Chilean *campesinos*, and as consequence, most of the Mapuche people were displaced. The military offensive campaign was initiated in 1859 and lasted until 1882, and it was denominated *Pacificación de la Araucanía* (Pacification of the Araucanía). During those not pacific 24 years, the military forces implemented an invasion plan, known as the war of extermination *(Guerra de exterminación),* that gradually pushed the frontier to the south. In 1866 the lands south of the Biobío River were declared by law as "state territory" (*territorio fiscal*), and the secured territories were controlled not only by forts or military occupation but also by a rapid colonization plan (Sauer, 2015, p. 167-173).

During the Pacification of the Araucanía, the Chilean state also implemented a political and ideological campaign in order to justify the military offensive and land usurpation (Bengoa 2004, p. 311-336). The Mapuche were depicted as savages in the printed press as well as in the public discourses by politicians of those years. As a recent and Modern state, Chile was aiming not only to unify

the national territory (the Arauco province was created in 1852 CE) but also bring “progress” and modernization mainly through the exploitation of natural resources (Murillo Sandoval 2015). As part of this progressist impulse, the Chilean state hired European scientists and naturalists. The main objective was to develop scientific research and create investigation institutions (Universities and Museums), but also to get an accurate account of the available natural resources of the territory and their distribution (Zaldivia 2005).

Among the list of foreign naturalists and travellers who visit Southern Chile we can mention Claudio Gay from 1835 to 1836, Charles Darwin in 1839, Ignacio Domeyko in 1845, Paul Treutler between 1851 and 1863, Rudolfo Philippi from 1852, and Edmond Smith in 1853 (Camus & Solari 2008, Camus 2005, Otero 2006).

The diaries and testimonies written by these travellers mention the existence of dense forests, as well as open fields. Domeyko mentioned that in the surroundings of the abandoned Tucapel fort (Tucapel River in the Cañete Comune, 37°47’S), it was possible to find oak trees of about 200 years old, suggesting that after the Biobío River was established as frontier there was a significant regrowth of the native forest (Camus 2006). Other areas, such as the cordillera and coastal range of the Arauco region, were described by the same author as a dense jungle (*selva*) where access was difficult if not impossible. Treutler depicts a similar landscape farther south in the coastal range near the Toltén River, where he observed a dense virgin jungle” (“*densa selva virgen*” Treutler 1958, p. 278).

In the main longitudinal valley of Southern Chile, the references to open fields were common until the Toltén River, where dense forests are mentioned to start dominating the landscape. Smith describes that “the country between the Chol Chol and the Cautín is fertile and thickly peopled” (Smith 1855, p. 202), although he also mentions that “the Mapuches all have an aversion to living in towns” (1855, p. 285). The author supposes that their settlement pattern is related to their “necessities as an agricultural and pastoral people—each one desiring to be sufficiently removed from neighbors to cultivate his crops, and pasture” (1855, p. 285). Smith did not travel south of the Toltén River and seems that during his journey he didn’t encounter many dense forests. In one of the passages, he describes passing by old and wide-spreading oak trees that gave the country “the appearance of a well-tended English park; but an occasional huge trunk, charred by fire and ready to fall, or already prostrate, told the melancholy tale that these sylvan monarchs are passing away” (1855, p. 202). Smith was convinced that the annual burning of grass was destroying the forests of Southern Chile, and although he did not clarify if it was a custom practised exclusively by indigenous people, he mentioned that it “is practised here as by the North American Indians” (1855, p. 202).

In the Imperial River valley, Domeyko described an immense well populated plain surrounded by cultivated hills with *canelo* and hazelnut trees established at the top (*Drimys wintery* and *Gevuina avellana,* respectively). A few kilometres to the southeast, in the surroundings of the Budi Lake (delta of the Imperial River), a similar panorama of agricultural prosperity was described. Domeyko mentions that the “*Indians*” kept their houses separated from their

neighbours by forests and hills ("*bosques y cerrillos*" Domeyko 1846, p. 102), and have next to their houses gardens and fields ("huertas y sementeras"1846, p. 52), where they grew wheat (*trigo*), barley (*cebada*), maize (*maiz*), chickpeas (*garbanzos*), potatoes (*papas*), linseed (*linaza*), and cabbage (*repollo*, p. 52).

During his first expedition to Southern Chile (1859 CE), Treutler visited the Toltén River where he encountered around 200 families living along the riverbank. He describes the terrains as plain and extraordinarily fertile in which wheat, broad beans, potatoes, and maize grew well (Treutler 1958, p. 330). On his third expedition to Southern Chile (1860 CE), Treutler went back to the main Toltén River valley, and he noticed that although the land was still fertile, large areas that used to be cultivated were abandoned because of the population drop. He wrote that these abandoned fields were "largely covered by bushes and even by trees in places that have been abandoned longer" ("*grandes trechos, antaño cultivados, se encontraba ahora yermos o estaban cubiertos en gran parte por arbustos, y hasta árboles en los lugares abandonados más tiempo"* 1959, p. 388). Although is unclear how long ago were these fields abandoned, the regrowth of the forest is usually mentioned in these descriptions to be fast. According to Otero (2006, p. 61), it can take between five to 15 years for an abandoned field to be covered by proper forest vegetation (if there is a source of seeds close enough).

Between the Toltén River and Valdivia, all testimonies described dense forests, especially in the coastal range and Andes Cordillera (Camus & Solari 2008). Domeyko mentioned that after crossing the Queule stream they entered "a jungle so dense and difficult to navigate, as if no one had passed through it

since the time when the first conquerors set foot on Araucanian soil" *("una selva tan tupida I difícil de transitar, como si por ella nadie hubiese pasado desde los tiempos en que los primeros conquistadores pisaron el suelo Araucano"* Domeyko 1846, p. 31). To reach the Toltén River from the South, Treutler followed an indigenous path in the coastal range described:

"so narrow, that only one horse could use at a time, because on both sides the virgin forest rose, impenetrable as a wall. Later, the vegetation was so exuberant that if no one went through the path for a few days, an infinity of vines and parasitic plants gathered in such a way that, to pass, it was necessary to clear the network they formed with a machete" ("*tan estrecho, que lo podía usar sólo un caballo, pues a ambos lados se elevaba la selva virgen, impenetrable cual una muralla. Luego, la vegetación era tan exuberante, que si nadie transitaba el sendero durante algunos días, se juntaban de tal manera una infinidad de enredaderas y plantas parásitas que, para pasar, era preciso despejar con el machete la red que formaban*" Treutler 1958, p. 315).

Charles Darwin visited the city of Valdivia (39°S) and its surrounding areas in 1835 and he described an uncleared forest where "the view of open plains was very refreshing, after being hemmed in and buried amongst a wilderness of trees" (Darwin 1839, p. 365). In the same area, he mentions that "the evergreen does not appear to be quite numerous; and the forest in consequence is coloured by a brighter and more lively green. In the same manner as in Chiloe, the lower parts are matted together by canes" (1839, p.364). In terms of forest composition, this description suggests non dominance by old-growth tree types (Armesto *et al.* 2009), and the presence of pioneer and shade-intolerant

species (likely to have taken over the territory and restored part of the native forest). As well as Treutler and Domeyko, Darwin noticed the presence of canes which according to his descriptions corresponds to *colihue* and/or *quila* (both members of the Chusquea genus). These plants are also considered indicators of altered or disturbed vegetation (Otero 2006, p. 34).

The plains of Osorno and La Union were the only open land mentioned in the Valdivia Province, which was also mentioned in the early descriptions of the 15th century (Bibar 1966, Camus 2005). Similar to the Toltén River Valley, the indigenous population of these plains was also decimated. When Osorno was first founded in 1558, around 200 thousand people were living in the plains, but by 1804 (after the re-foundation of the city) only two thousand persons were left (Otero 2006).

The existence of dense and exuberant vegetation was depicted as an obstacle for bringing progress to the Region. In the view of Domeyko, the colonization of the jungle and mountains was meant to benefit the "temperament" of the Valdivia Province. To improve the Region it was necessary to cut off the trees and cultivate the land because "until now have done nothing more than attract and conserve humidity and exhale evil miasmas" ("*mejora que se deberia al corte de los árboles i al cultivo de los terrenos que hasta ahora no hacen otra cosa mas que atraer i conservar la humedad i exhalar miasmas maléficos"* 1846, p. 99). Although the testimonies also report the existence of cultivation fields and indigenous settlements, the repeated references to the jungle and wood (*selva* and *monte*) instead of the term forest *(bosque*) highlighted the wild aspect of the territory. These descriptions contributed to the idea of an

uncivilized and unpopulated land, despite the decimated but still present indigenous populations.

From 1850, the Chilean Republic started a renewed colonisation of Southern Chile by attracting European migrants. Most of them were German families, but also included families from Spain, Belgium, France, Italy, and Switzerland. Each family received from the Chilean state between 200 and 500 hectares of land, and one of the first actions of the settles was to burn the forest to obtain clear land to cultivate and raise animals. New cities were founded, and during this same period, the train line was extended to Southern Chile, reaching Temuco (38° S) in 1891 and connecting Osorno and Valdivia in 1906. A significant portion of the forests was burnt as a result. Immigrants (particularly German's ones) were portrayed as having been able to "force the hand" against savage nature in Southern Chile, bringing civilization and prosperity to a previously empty and wild region (Valko 2010). This quasi-heroic vision of the immigrants echoed the civilizer discourse used to legitimize the Occupation of the Araucanía, and during the international fair of 1875, an ideal of a regional identity based on dominion over nature was popularized (Murillo Sandoval 2015).

Southern Chile vegetation experienced major changes after the second half of the 19th century. The global pre-industrial and industrial demand for timber caused extreme deforestation and soil erosion (due to mining and the golden age of timber). During the California "gold rush", large amounts of wheat produced in Southern Chile started to be exported not only to California, but also to Perú, Argentina, New Zealand, and England. The highest rates of wheat

production were registered between 1865 and 1926, causing a demand for more cultivation land that intensified the occupation of indigenous lands in the Araucanía Region (Otero 2006).

After 1882 CE, the Chilean state forced the Mapuche populations to reduce their territories, creating indigenous communities and reductions. Big fires were induced In Southern Chile after 1882 CE with the argument of creating agricultural lands. Araucanía was then named El Granero de Chile which translates as the granary of Chile or the Chilean wheat bowl (Ulloa & Barton 2021). These fires consumed approximately 300 thousand hectares leaving not only open territories but also really eroded land. In terms of cultivated lands (and considering altogether the nowadays Biobío, Araucanía, Los Ríos and Los Lagos Regions Provinces), if by 1878 there were around 30 thousand planted hectares, by 1915 there were 168 thousand planted hectares (Camus 2006, p. 113). For the Mapuche communities, the state policies translated into the loss of territories and their resources (including pastures for animals), causing economic impoverishment. The low productivity of the lands assigned by the state (Ulloa & Barton 2021), and the impossibility to keep large groups of livestock resulted in Mapuche groups becoming the lowest socio-economic segment of Chilean society, along with the rest of the indigenous groups in the country.

The agricultural system implemented in Southern Chile required the constant burning of forests (Klubock 2014). The settlers argued that the ash layer from the fires was beneficial to grow cereals, so they requested more land to burn and turn into agricultural fields. After the first world war and during the economic

recession, around 280 thousand hectares were assigned in different parts of the country to impulse a second wave of colonization. By the middle of the 20th century, the average of hectares consumed by fire was estimated at 50 thousand per year (Otero 2006, p. 126).

In 1931 the Law of Forest (Ley de Bosques, Decreto Supremo N° 4.363) was promulgated in order regulate the use of forest territories and protect them, but in practice, native forest exploitation was unregulated until 1950 and described as “irrational” by a sector of the national Congress (Camus 2006, p. 115-116). Around those years, exotic forestry plantations were introduced in Southern Chile (mainly related to the paper mill industry) along with intensive crop mono cultivation systems. The Neoliberal economic Model imposed during the Chilean Military dictatorship (1973-1990) promoted the expansion of forestry monoculture which in addition to extensive farming, caused a homogenization of the landscape and limited forest regeneration (Armesto *et al.* 2009). During the Military Dictatorship it was also created the National Forest Corporation (Corporación Nacional Forestal, CONAF), institution in charge of preserving the natural parks and reservoirs. The Mapuches communities were directly affected by these events because part of their ancestral land and forest were burned down to plant Monterrey Pine and Eucalyptus, but also traditional forest foraging and other forest-related activities were in some areas restricted due to the conservationist regulation implemented in national parks (Klubock 2014). During the last decades, the conflict between the forestry monoculture industry, the Mapuches communities, and the Chilean State has increased. Mapuche communities are not only demanding the restoration of their usurped ancestral

lands (Di Giminiani 2015), but also the restoration of an ecological order ensuring the use of the native forest (Klubock 2014).

5.4 Continuities and discontinuities in the temperate forest of Southern Chile

The revision of the historic testimonies and other available records suggest that the temperate forests of Southern Chile were not pristine or virgin before the arrival of the European conquerors. Through the centuries, the descriptions and narrations mentioned the existence of open lands as well as forests. Similarly to North America (Denevan 1992, Pyne 1997), the testimonies emphasising Southern Chile's dense forests and exuberant vegetation were written during the 19th century. These descriptions most likely reflected a forested landscape resulting from population decimation and abandonment of cultivation fields due to warfare with Spaniard's invaders and the subsequent subsistence and economic changes (Camus & Solari 2008). Most of the traditional knowledge related to the different uses of temperate forest resources comes from the Mapuche Culture. Also, most of the ethnographic analogies used in the archaeology of Central and Southern Chile were based on ethnography and ethnoarchaeology carried out among Mapuche communities (Campbell 2011, Sanhueza *et al.* 2007). Several ethnographic, ethnohistorical, and ethnobotanical studies have highlighted the close relationship between the Mapuche cosmovision and its landscape, not only in utilitarian terms but also acknowledging the symbolical and ritual sphere associated with the

environment and its resources (Adán *et al.* 2004, Villagran 1998). Although is clear that several aspects of the Mapuche culture have changed over the centuries, other show continuity from pre-Hispanic times.

Closely related to the expansion and retreat of the forest are the ecologic and economic effects of the old-world taxa introduced after 1550. Some authors have referred to this process as a conquest in ecological terms (Camus & Solari 2008), or ecological imperialism (Crosby 1993). Along with the new cultivars and animals deliberately introduced, new diseases, pests, and weeds were also brought affecting the native biodiversity. While some weeds spread rapidly over vast territories without any utilitarian use, others were incorporated into the traditional indigenous and popular medicine. In the Indigenous Botanic compilation written by Wilhelm de Möesbach, a capuchin priest who lived in Southern Chile between 1920 and 1960, several non-native weeds are described with their Mapudungun given names, medicinal properties, and mode of use according to the Mapuche informants. Among them we can mention *Huinca llantén* (*Plantago major* L.), *alca-curi* (*Urtica urens* L.*, Urtica dioica* L.), *ñilhue* (*Sonchus oleraceus* L.) and even some moss like *pitrongma* (*Funaria hygrometrica*, Wilhelm de Möesbach 1992). In relation to cultivated species, some of them mentioned in the early testimonies to be popular (like *Bromus catharticus, Bromus berteroanus, and Bromus mango)* were centuries later rarely consumed or cultivated (Coña 2017, p.102), and even considered extinguished today as in the case of *Bromus mango* (Pardo & Pizarro 2016, p. 142). When old world taxa like wheat and barley were adopted, they replaced maize in some cases. The fermented drink "*chicha*" was traditionally made of

maize or berries (strawberry one was the most appreciated) and then was made from wheat or apples. By the 18th century, other plants like quinoa and *madi* were less common or referred to as cultivated by the ancient people (*los antiguos*), while by the 19th century crops like chickpeas, cabbage, and linseed were mentioned to be commonly cultivated. Potatoes, chili, and beans seem to be staple over the centuries, and recently, since the rebranding of quinoa as a superfood, Southern Chile varieties of *Chenopodium quinoa* have been "rescued", investigated, and reintroduced (Bazile *et al.* 2015).

The Southern Chile´s "sheep from the earth" (*oveja de la tierra*) or *chilihueque* seemed to be completely replaced by the Old world livestock (sheep, horse, and cattle). Until the 17th century the mentions of these southern camelids indicate that they were sacrificed during special ceremonies and meetings (Goicovich 2018). Nowadays is not clear if they were just replaced by exotic livestock because it was easier to breed and offered more benefits. Al least in a temperate climate, Old world animals presented more advantages in terms of food, leather, fibre, transport, and as plow animals (Crosby 1993, p. 173). Some authors have suggested that the introduction of Old world livestock might have also introduced new diseases or parasites that decimated the population of southern camelids (Bonacic 1991).

More difficult is to establish the changes and effects associated with the use and distribution of non-domesticated taxa, particularly with woody plants because what might be considered today as the ecological or natural distribution range of a species might actually reflect anthropic management (Hayashida 2005). As a kind of a consensus, in Chile, a tree is considered

native if it was present in the territory before the Spanish conquest, so trees introduced to the territory during pre-Hispanic times are classified as native (Silva 2010). The native concept helps then to masks the anthropic pre-Hispanic factor in relation to forest composition. For instance, according to Rosales (1877), the *keule* o *queule* (*Gomortega keule,* a tree that produces an edible drupe) was commonly found in the riverbank of the Queule River (hence the name of the river), and there are reports from the early 20th century indicating its distribution down to 40 °S (Reiche 2013). Additionally, pollen evidence from the Budi Lake (38°42'S) indicates a wider distribution of the species between the 6.300 to 3.000 BCE (Abarzúa 2009). Today, the tree is an endangered species and presents an ecological distribution restricted to the coastal range between 35°37′S to 37°41′S (Muñoz-Concha, Farías & Méndez 2015). In my opinion, the historical data not only suggests a wider geographical distribution of the tree in the past but also opens the possibility for the tree to be transported and managed by pre-Hispanic groups. The existence of a different southern *Gomortega* specie was mentioned by native informers to the botanist Hipólito Ruiz in the 18th century who wrote on his travel memoirs "I have not seen any but the stones of the fruits" (1910, p. 128), nevertheless, this southern queule tree has never been found or described botanically (Muñoz-Concha & Garrido-Werner 2011).

Apple trees were widely distributed in Southern Chile. During the 17th century, they were described to exist nearby Spanish settlements, for example, Núñez de Pineda y Bascuñán (1948) describes them in relation to the ruins of La Imperial. Later, during the 19th century, forests of apple trees were described to

be found around the city of Valdivia before the arrival of the European immigrants (Camus & Solari 2008). Apple trees became important among Mapuche people (Coña 2017, p. 150-156), even so, that an entire region of Argentinian indigenous territory was known as the apple country (*el país de las manzanas*), and its people were known as *manzaneros (Delrio 1997).*

Chapter 6: Wood charcoal analysis as a methodological proxy

6.1 Wood charcoal approaches to past vegetation and wood uses

The focus of the project is the analysis of wood charcoal remains from archaeological sites of Southern Chile. Wood charcoal is the most frequent and ubiquitous vegetal remain found in archaeological sites (Smart & Hoffman 1988), because after carbonization is not attractive for microbiological decomposers due to its lack of nutrients (Moskal-del Hoyo, Wachowiak & Blanchette 2010). Originally wood charcoal analysis (also known as anthracology, from the Greek term for coal *anthrax*) was mainly used as a proxy to reconstruct past environments in a similar way to pollen analyses (Chabal *et al.* 1999). Since 1938 wood charcoal from archaeological sites started to be studied (Kabukcu 2018), and shortly after (Godwin and Tansley 1941), the issue of how representative are these remains in relation to past vegetation was raised by considering the cultural aspects inherent in the archaeological samples. Although there is a still ongoing debate about the truly palaeoecological value of wood charcoal analysis, in archaeological terms it has been established that anthracology can inform about wood taxa use and selection by past human societies, as well as the environmental context of the archaeological sites in relation to a biotope, plant communities and exploited territories (Théry-Parisot & Henry 2012).

The majority of the wood charcoal recovered from archaeological sites are fuel remains, and therefore, they are the material evidence of people-woodland interactions. Because fuelwood gathering partly depends on the ecological

factors and environmental conditions, wood charcoal analysis informs about the different species and vegetal associations available and accessible to people in the past (Asouti & Austin 2005, Smart & Hoffman 1988). To obtain an integral panorama of people-woodland interactions, a series of social, economic, technological, and cultural aspects must also be considered. Similarly to the procurement of other resources such as food or water, fuel collection is usually incorporated into the daily activities of a social group (Salavert and Dufraisse 2014), and their consumption and management reflect more than the combustion needs of a certain household or group. It also reveals spatial networks of supply areas (Robledo 2021), and fuel use strategies adapted to their environmental and vegetation setting, which are influenced by cultural perceptions. People-woodland interactions are the result of complex cultural and ecological processes involving a series of interacting factors, such as climatic and vegetational conditions, landscape modification, and woodland management practices (Dufraisse 2012, Kabukcu 2018). The incorporation of ethnoarchaeological and ethnobotanical approaches has been essential to understanding the complex feedback cycles between these factors (Picornell-Gelabert 2018). Firewood and woodland management, which involves cultural, technical, and economic aspects (Delhon 2018), directly affects the vegetal composition and species availability, and vice versa, the vegetal composition could eventually affect firewood management practices (considering a simplified scenario).

The selection or preference for certain woodfire and woody resources is one of the recurring topics when discussed wood charcoal analysis as a proxy to study

past vegetation and landscape changes. Under the assumption that woodfire could have been selected by people among the available plants, the wood charcoal record could then reflect a partial number of species showing inaccurate frequencies or distorted distributions. Early approaches, such as the principle of least effort (Shackleton & Prins 1992), proposed that in environments with abundancy of woody taxa a selection over certain types can be expected, and in contrast, in environments with restricted woody resources all taxa are likely to be exploited. The general consensus reached after decades of wood charcoal analysis, are in first place that selection cannot be only understood in taxonomical terms, and in second place the wood charcoal assemblages from long-term domestic contexts tend to represent to certain extend the distribution and frequency of woody resources. These principles have been derived considering data from ethnographic and ethnoarchaeological sources (Maxwell 2011, Peña-Chocarro *et al.* 2000, Picornell 2009, Vidal-Matutano 2013), experimental approaches (Théry-Parisot, Chabal & Chrzavzez 2010) and anthracological analysis (Chabal, Fabre, Terral, & Théry-Parisot 1999, Marston 2009). Altogether these sources show that the qualities that define a good firewood (such as flammability, calorific value, reached temperature, flame height, and combustion durability) are not only related to each specific taxonomic species, but to other parameters such as its state (green, dead, or even fossilized), humidity level and diameter (Carrión 2005, Chabal 1988, Chabal *et al*. 1999, Delhon 2008, Solari 2000).

In other type of contexts were fire and fuel are destined for specific purposes, such as ceremonial or ritual burning (including cremations), or specialized

production (e. g, metallurgy), the selective versus nonselective use of fuel varies from case study to case study (Heiss & Oeggl 2008, Shimada & Craig 2013).

More recently, a series of taphonomy approaches and digital image methods (diameter estimation and measurement of specific wood anatomy features) have been incorporated into wood charcoal analysis (Caruso Fermé et al. 2018, Dufraisse et al. 2022). As a result, a series of new issues have been addressed, such as woodland growth conditions, social practices related to woodland management and fuel collection, hearth management, combustion itself, as well as depositional and post-depositional processes (Allué, Euba & Solé 2009, Kabukcu & Chabal 2021, Théry-Parisot, Chabal & Chrzavzez 2010).Nowadays, wood charcoal analysis presents the appropriate methodological and interpretive approaches to address past vegetation changes concerning anthropogenic forest clearance.

Anthracological approaches have been used in other parts of the world to study woodland transformations and deforestation, mainly in relation to the Neolithic transition (Asouti & Hather 2001, Asouti *et al.* 2015, Salavert & Dufraisse 2014, Moskal-del Hoyo 2021). In the tropical forest of Amazonia, wood charcoal analysis from archaeological sites has been studied in relation to changes in forest composition and as evidence of anthropogenic forest. Studies from three sites of the Brazilian Amazonia indicate that agriculturalist/horticulturist groups (1050 BCE to 1400-1650 CE) promoted the development of secondary vegetation and concentrating useful species around archaeological sites

(Scheel-Ybert, Fernandes Caromano & Waisman De Azevedo 2016). The data from Forest of Nouragues in North Amazonia (French Guiana), indicates that different human activities have diverse impact on subsequent vegetation once land management ceased, resulting in anthropogenic bamboo-like thickets (Bodin *et al.* 2020). In other geographical areas such as the Northen Sector of the Andean Pampean Hills (Chaco Serrano Forest), topics such as the shaping of the landscape by Late Holocene groups has been proposed using wood charcoal data (Robledo 2021).

For the temperate forest of South America (Chile and Argentina), most wood charcoal studies have focused on forest resource use and exploitation by pre-Hispanic hunter-gatherer groups (Caruso Fermé & Civalero 2014, Caruso Fermé 2019, Solari 1993, 2009), Although there are few wood charcoal studies for Colonial and Ethnographic times (Piqué i Huerta 1999, Solari 2016, Soria-Galvarro 2022), woodland transformation and its relation to anthropic activity has mostly been studied by environmental historians from the time of the European contact onwards (Camus & Solari 2008, Camus 2005, Lara et al. 2012, Otero 2006).

6.2 Wood charcoal interpretation

In general terms, the environmental interpretation of wood charcoal depends firstly on the archaeological context. Charcoal samples should be obtained from domestic firewood representing long term activities (Kabukcu & Chabal,

2021, Théry-Parisot *et al.* 2010). Because the wood charcoal scattered or dispersed in archaeological layers from domestic sites is the result of several firewood collections and burning events over a long period of time, it is supposed to represent a more reliable vegetal image from the surrounding environment. In contrast, wood charcoal from a particular combustion structure (oven or fireplace), could correspond to a single burning event (short lived deposit) and might provide a brief but also partial image of the vegetal surroundings.

Depending on the specific ecological conditions, a long-term occupation should correspond to a significant number of identified taxa (30-40). Over the last ten years, the representativity of these two types of anthracological deposits, the disperse versus the concentrated ones has been review a contrast with more archeobotanical data. According to Henry and collaborators, (2020) in some contexts, the size of the fragments (over 4 mm versus 4-2 mm) can influence the taxa results in a more notorious way than the usual differentiation between dispersed versus concentrated charcoal.

Secondly, the wood charcoal should reflect an appropriate sampling of the archaeological layers. An extensive spatial sampling should provide enough wood charcoal fragments to achieve representative samples (Kabukcu & Chabal 2021). Although the minimum number of identified charcoals depends of each context, over the years some estimations have been proposed. For temperate regions of Europe, the recommended number of identified wood charcoal fragments is around 250-400 per stratum or archaeological layer

(Kabukcu & Chabal 2021, p. 13), and for tropical regions like the Amazonas, around 200-300 identified fragments per sampling level are reliable sample size (Bodin *et al*. 2020b). Other authors propose a minimum of 400 fragments for Tropical areas (Dotte-Sarout, Carah & Byrne 2015). Although for Southern Chile there are not analysed samples big enough to propose a regional minimal number of identified charcoal fragments, for the Patagonian Forest region, which is less diverse in comparison to Southern Chile, a minimal of 100 identified fragments per layer has been proposed (Solari 2000).

Thirdly, and if the previous conditions were fulfilled, then the wood charcoal spectrum should be reproducible in contemporary layers across the site, but also be coherent with stratigraphic/chronological horizons from other similar sites and with other type of environmental information (Théry-Parisot, Chabal & Chrzavzez 2010).

Due to the excavation and sampling strategies that will be detailed for each archaeological site, the analysed wood charcoal samples do not completely fulfil the ideal guidelines just described. Nevertheless, the aim of the dissertations is not to obtain a quantitative and statistical reliable wood charcoal spectrum with unquestionable paleoenvironmental value. In methodological terms, this project is the first attempt to obtain a more general perspective on forest landscape in relation to the pre-Hispanic archaeological sites of Southern Chile. In interpretative terms, and being aware of the methodological limitations, the wood charcoal results can inform about what taxa and plant communities used to grow in the area near the archaeological sites, and how

these taxa can inform about ecological habitats in the area (Smart & Hoffman 1988). The identification of certain taxa indicates their existence in the past, but it is also indicative of other ecological and social aspects, like variations in the distributions of species over time (taxa identified in the archaeological record but absent in the present), and the clearing of the forest (by identification of secondary shrubs). As it is discussed in the following section, there are not proper wood charcoal sets to compare to, and there is still a lack of experimental background on native woody species, but at the same time there is great potential for wood charcoal studies in Southern Chile.

6.3 Historical development of wood charcoal analysis in Southern Chile

Considering the regional context, archaeobotany is a recent discipline in Southern Chile. With the exception of Monte Verde-1 (Dillehay et al. 2008), systematic recovery and posterior analysis of archaeobotanical remains started being implemented in the 1990s, particularly in Mocha Island (Roa *et al.* 2018, Rojas & Cardemil 1995). Charred seeds analysis or carpological analysis is the most frequent source of archaeobotanical data, and in comparison, wood charcoal analysis is still an underdeveloped field in the region. Traditionally, archaeobotanical analysis has been focused on the identification of edible resources present in the archaeological record. Previous Southern Chile study cases where archaeobotanical approaches have included wood charcoal and charred seeds analyses have proved complementary results. The implementation of both analyses offers integral data in terms of subsistence,

availability of vegetal resources, and characterization of the vegetal surrounding of archaeological sites (Lehnebach *et al.* 2008).

In order to give a brief historical perspective on wood charcoal analyses in Southern Chile, a revision of different published and unpublishes sources was conducted, including papers, reports, book chapters, dissertations, and conference posters. The main objective was to identify the aims behind each of the analysis, the type of sampling and other methodological considerations, and the integration with other archaeobotanical or environmental data sets. Geographical variables were also considered, as well as the type of site (habitational or ritual), and archaeological Period. The Chilean Patagonia was also included in this revision, because the development of the archaeobotany and wood charcoal analysis in Southern Chile it is strongly linked to this vast region.

More than 20 sources were considered (table 2), informing on more than 40 archaeological sites. The first charcoal paper was published in 1989, and from then until most of the 1990's, all the analysis were concentrated in the Magallanes region, Chilean Patagonia. From 2004 papers outside the Patagonia Region started being published, and during the third International Anthracology Meeting (2004, Cavallino-Lecce, Italy), Maria Eugenia Solari presented a synthesis after 15 years of wood charcoal analysis in Chile. For years M.E. Solari was the only wood charcoal specialist in Chile (and probably South America), and in her review she mentioned the low integration and scarcity of anthracological analysis (2008).

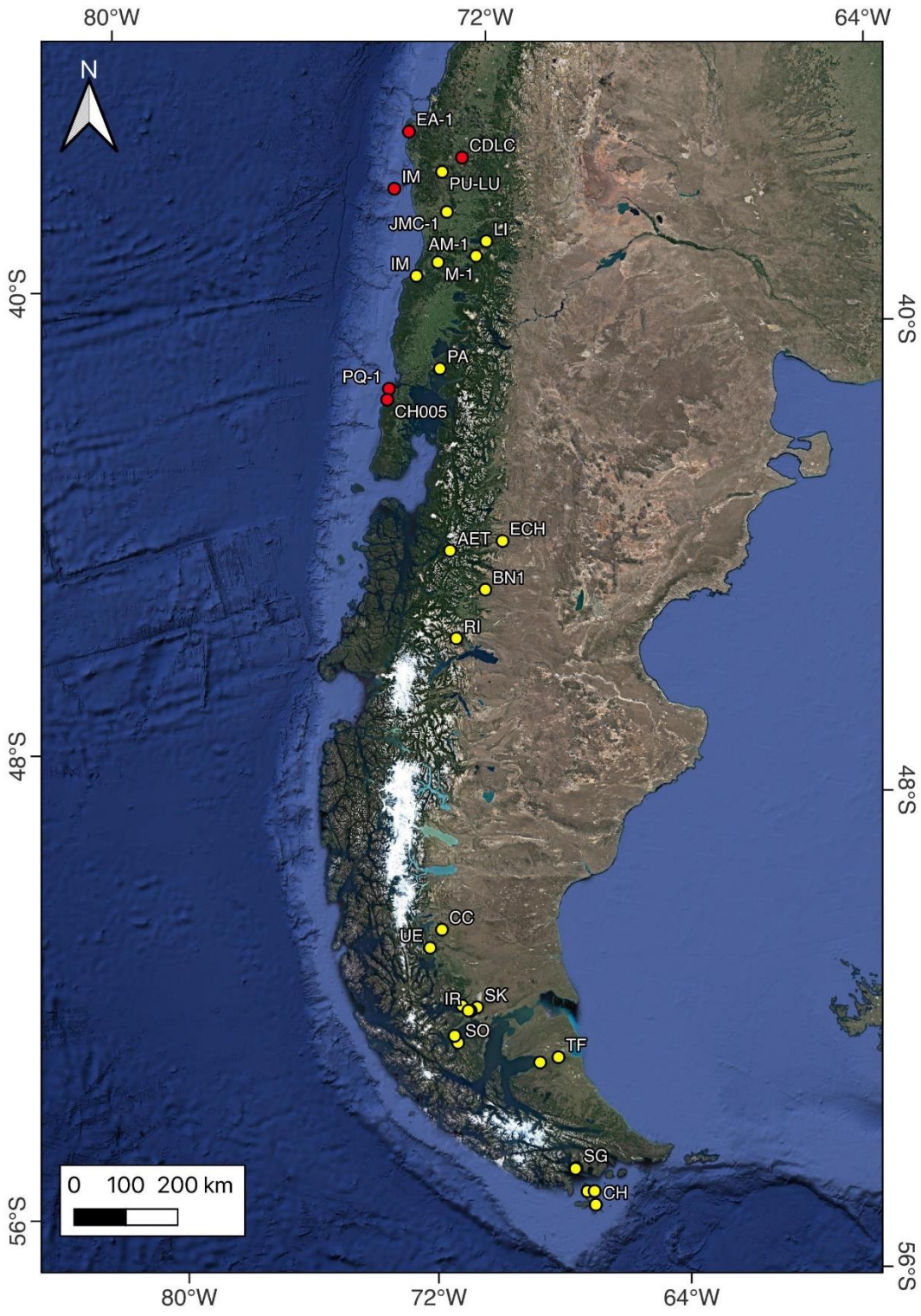


Figure 6: Geographical location of sites with wood charcoal data. Abbreviations are listed in table 2 (red colour indicates wood charcoal analysis conducted by the author, and yellow colour indicates published data).

Table 2: Archaeological sites with wood charcoal analysis data from Southern Chile and Patagonia (listed from north to south).

Archaeological sites and abbreviations	References
El Arenal-1 (EA-1)	Buhring *et al.* 2023
Cueva de los Catalanes (CDLC)	Roa et *al.* 2023
Mocha Island (IM): P5-1, P29-1 and P31-1	Delgado 2017
Puente Quilo 1 (PQ-1)	Sierralta *et al.* 2023
Chepu 005 (CH005)	Rebolledo et al. 2023
Purén-Lumaco (PU-LU): LU-8, LU-16, LU-34, PU-87, PU-132, PU-165, PU-166.	Solari 2014
Villa José Miguel Carrera - 1 (JMC-1)	Mera & Munita 2021, Solari 2016
Liucura Valley (LI): LI-H, LI-2A, LI-3A, LI-12A, LI-19	Solari 2014
Alero Marifilo-1 (AM-1)	Solari *et al.* 2004, Lehnebach *et al.* 2008
Millahuillin-1 (M-1)	Solari 2016
Mancera Island (IM): Castillo de Mancera and Plaza Colonial	Soria-Galvarro 2022
Piedra Azul (PA)	Gaete et al. 2004
El Chueco (ECH)	Riquelme-Toro *et al.* 2016
Alero el Toro (AET)	Riquelme-Toro *et al.* 2014
Baño Nuevo 1 (BN1)	Riquelme-Toro *et al.* 2014
Rio Ibáñez (RI): Alero Fontana and Alero el Potro	Solari 1993
Cerro Castillo (CC)	Solari 2009
Última Esperanza (UE): Cueva del Medio and Cueva Lago Sofía	Solari 1993
Seno Skyring (SK): n3 escarpada, n14, n16a, n16b	Solari 1993
Isla Riesco (IR): Ponsonby	Solari 1998, 2003; Solari *et al.* 2002
Seno Otway (SO): Punta Baja and Bahía Colorada	Solari 1989-90, 1997
Tierra del Fuego (TF): Marazzi and Tres Arroyos	Massone & Solari 2017
Seno Grandi (SG): Navarino 1 and Bertrand 1	Solari 1992,1993, 1993-94
Cabo de Hornos (CH): Herschel 1,2,3, 4; Wollaston 7 and 8; Bayly 1	Solari 1992,1993, 1993-94

From 2008 there are publications in Southern Chile (Lehnebach *et al*. 2008), and in the last ten years, particularly after 2014, wood charcoal analysis started to be conducted in the Araucanía Region (Purén-Lumaco Valley, Liucura in Pucón, And Villa José Miguel Carrera-1, Labranza), Los Ríos Region, and other places in Patagonia, such as Tierra del Fuego. Is also during the last ten years, when new reserchers started to study materials from areas where little or no previous wood charcoal analysis was done, like the Aysén Region (Riquelme-Toro, Méndez & Théry-Parisot 2014, 2016), Isla Mancera in Los Ríos (Soria-Galvarro, 2022), and Chiloé in Los Lagos Region (Rebolledo *et al.* 2021, Sierralta Navarro *et al.* 2024).

Considering the location of all the sites with wood charcoal information (figure 6), there is a clear concentration around specific geographical zones that reflects the development of research archaeological projects in the mentioned regions. The areas without any wood charcoal analysis are the ones where no research projects have been conducted, or where they just started to be implemented. In general wood charcoal analysis is not considered among the requested material analysis part of the contract Archaeology programs (but it frequently includes charred seed analysis). The exception is the Piedra Azul site, where some wood charcoal was analysed as part as rescue archaeology program (Gaete *et al.* 2004).

In terms of archaeological chronologies, most of the studies correspond to contexts and sites dated from to the Late Holocene onwards (since the 5000 BP or around the 3000 BCE). This is not surprising because most of the known

archaeological sites are registered since the Late Holocene, which in a macro-regional level is related to a population growth (Campbell & Quiroz 2015, Perez *et al.* 2016).

The main aim shared among most of the reviewed sources is to study the use of firewood among the past societies, and secondly, to characterize the environment of the corresponding archaeological sites. This show that wood charcoal in Chile has been strongly orientated to archaeobotanical topics and rarely linked to palaeobotanical studies. The exception is the analysis in Ponsonby (Riesco Island, Patagonia), where besides exploring the relation between hunter gatherer groups and their forest environment (Solari 1998, 2003), wood charcoal analysis was integrated to a multidisciplinary environmental approach (Solari *et al.* 2002).

In relation to the methodological approaches to wood charcoal, all the studies were focused on taxonomical identification, and in a third of the analysed sites the taphonomy aspects were also reported (but only in studies post 2004). Regarding the integration with other types of archaeobotanical evidence, only few of them explicitly mentioned the contrast with other data. Nevertheless, since the revision was not conducted systematically among all archaeobotanical sources and not just wood charcoal, it is possible that archaeobotanical studies referring or citing to wood charcoal data were overlooked.

6.4 Methodological aspects of the analysis

6.4.1 Archaeological sites and sampling

For strategic reasons, the archaeobotanical material analysed was already obtained from archaeological sites excavated in the last 15 years, where archaeobotanical sampling was implemented. The sites were selected considering their chronology, the availability archaeobotanical samples, and their geographical location. In terms of chronology, all the chosen sites have reported dates and/or diagnostic archaeological materials from the Early to the Late Ceramic Period, and in some cases, until Historic Times. In most of the considered sites, charred seeds have already been identified, and the data and reports were available. All the samples were obtained from habitational/ domestic sites, which provides more reliable data regarding environmental aspects in comparison to non-domestic contexts (Théry-Parisot, Chabal & Chrzavzez 2010). A total of four archaeological sites were analysed, three of them corresponding to open-air sites, and one to a cave context. In geographical terms, the sites represent different landscapes and environments. Three of them are located in coastal areas, including an Island, and one in the central valley. Table 3 shows a summary of the analysed sites, and their location is shown in figure 7.

Table 3: Location of the sites considered in the analysis of this dissertation

Archaeological site	Coordinates (WGS84, UTM 18H)	Region
El Arenal-1	-622862 E, -5863012 N	Biobío
P5-1, Isla Mocha	-595980 E, -5754370 N	Biobío
P29-1, Isla Mocha	-593760 E, -5756570 N	Biobío
Cueva de los Catalanes	-725638 E, -5812890 N	Araucanía

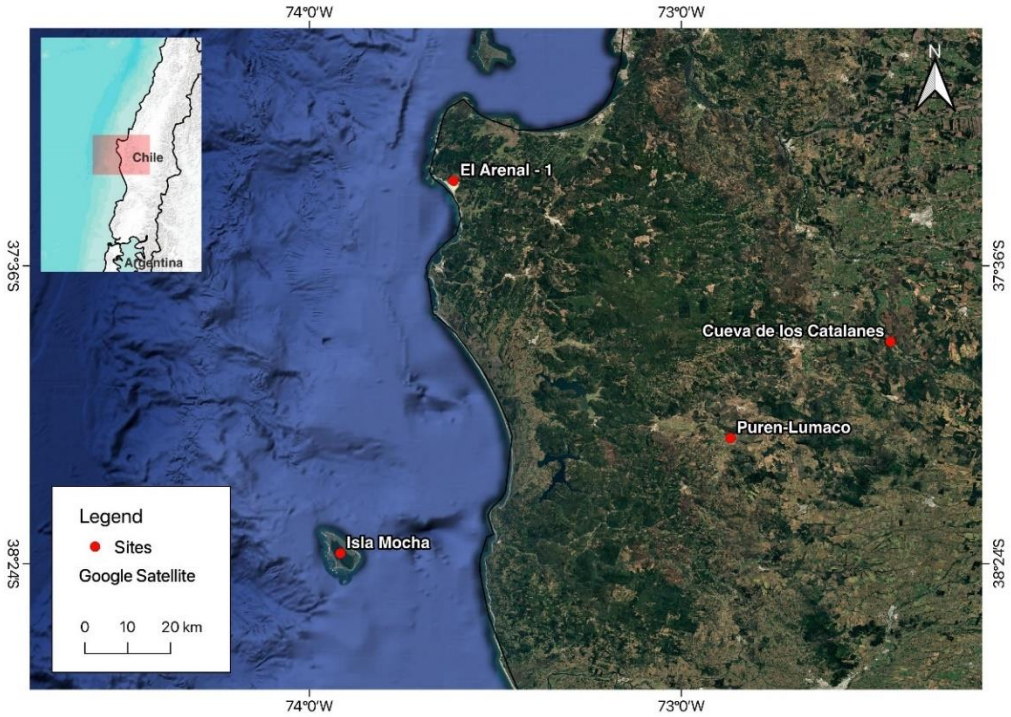


Figure 7 : Map of the sites considered in the analysis of this dissertation

The samples considered in this project were obtained mostly during the last decade (the oldest excavation was conducted in 2012, in the P29-1 site of Mocha Island). The sites were excavated by different archaeological teams,

using different methodologies, and the archaeobotanical sampling was also different in each site. For this reason, the sample provenience information is detailed for each the sites in their respective chapter.

Independently of whether the samples were obtained by flotation, dry sieving, or by handpicking during the excavation, they were weighted and separated using sieves. Two different mesh sizes were used (4mm and 2mm), separating the charcoal fragments into three main different size categories: over 4mm, between 4 and 2 mm, and under 2 mm (in some sites, where large fragments were recovered, an over 8 mm category was also registered). Mesh sizes were selected following size categories used in previous wood charcoal sampling studies (Chrzazvez *et al.* 2014, Vidal-Matutano *et al.* 2017). Experimental approaches have indicated that the analysis of over 2 mm and especially over 4 mm fragments provide reliable results in relation to the initial proportions of taxa burned as fuel (Chabal et al. 1999, Chrzazvez et al. 2014, Kabukcu 2018), although more recent approaches have suggested that the size can influence the taxonomical results (Henry *et al.* 2020). Taking this into consideration, fragments over 4 mm were analysed first, to then analyse the over 2 mm fragments. Although in most of the samples all charcoal fragments were analysed, subsampling was applied in big samples (usually over 100 fragments) using accumulation curves (Kabukcu & Chabal 2021).

Wood charcoal analysis was conducted by observing the three anatomical sections of wood (transversal, longitudinal radial, and longitudinal tangential sections). Charcoal fragments were manually fractured using a scalpel to

obtain fresh and clean cuts of the different anatomic sections, and then, they were observed under a reflected light microscope (Olympus BX60, 100X-500X magnification). Because wood charcoal fragments under 2mm are too small to handle and fracture in the proper sections, and they frequently do not present enough diagnostic anatomic features (Lehnebach *et al*. 2008), under 2mm charcoal fragments were only analysed in samples with no bigger fragments.

6.4.2 Taxonomic identification

The taxonomic analysis consisted of the recognition of microscopic features (mainly cellular arrangement, presence and frequency of different cell types, and the presence of specific cellular features) in order to classify wood charcoal remains according to order, genus, family, and species (if possible). The taxonomic identification was conducted by direct comparison using a personal reference collection of charred modern specimens (table 3, appendix A). To this date, the reference collection contains over 100 taxa, representing 44 families and 90 native and endemic genera of woody plants of Southern Chile. As a reference, considering the native sclerophyllous and lauriphyllous forests of Chile, the number of woody species correspond to around 180 genera (Gómez, Salazar & Montenegro 1999). The collection includes trees, shrubs, woody climbers, vines, lianas, bamboos, and other lignified plants that are usually not considered woody plants but could be used as fuel. The taxonomic identification was complemented by using published anatomical wood atlases of South American tree species species (Díaz-Vaz 1979, Miles 1978,

Montenegro 1984, Rancusi, Nishida & Nishida 1987, Torricelli 1937, Tortorelli 2000, Wagemann 1949), as well as pertinent papers and doctoral dissertations on the subject (Ancibor & Pérez de Micou 1995, Andreoni 2014, Caruso-Fermé 2012, Franch Bach *et al*. 2022, Marconetto 2008, Pérez de Micou 2002, Piqué i Huerta 1999, Solari 1993).

Fragments were classified as identified when they exhibited enough distinctive anatomical features to be assigned to a particular taxon, and the taxonomic nomenclature is presented according to the catalogue of the vascular plants of Chile published by Rodriguez and collaborators (2018). In terms of taxonomic accuracy, previous anthracological studies have highlighted the difficulty to identify species among some genera (*Berberis* or *Nothofagus* as discussed by Caruso-Fermé 2012), or a specific genus among some families. For example, the Myrtaceae family compromises 8 genera and 22 species in Southern Chile, with 13 of the species catalogued as endemic. Some of the cellular features characteristic of each of the species (such as type of punctuations, or number of bars in the perforation plates, or quantity of vessels/ rays per mm^3), were not always visible in the wood charcoal fragments due mainly to taphonomic alterations. As methodological caution the Myrtaceae family was only identified to sub family level, distinguishing two types; the Myrtaceae type A corresponds to diffuse porous wood with small vessels (around 30 µM), heterogenous rays, and presence of scalariform plates (Rancusi, Nishida & Nishida 1987). The taxa grouped in this type includes the genera *Luma, Myrceugenia* and *Ugni,* while Myrtaceae type B comprises the *Amomyrtus*, *Blepharocalyx* and *Tepualia* genera. As it is described with more details in the appendix B, it is also relevant

to take into consideration that some of the woody species can hybridize with other species (such as the *Laurelia* and *Laureliopsis* genera, Alarcon & Donoso 2004).

Fragments were categorised as unknown when distinct anatomical features were recognised but it was not possible to assign them to any taxon. This could occur if they are not part of the reference collection, they have not been described in an anatomical wood atlas, or they have not been reported by previous studies. In comparison, there are more anatomical descriptions and publications of tree taxa (especially if they are valuable or profitable in commercial terms), and less information about minor woody taxa like shrubs and vines. If more than two unknown fragments presented the same anatomical features, they were grouped as Unknown A, Unknown B, Unknown C, and so on.

Fragments were classified as un-identifiable when it was not possible to observe all anatomical sections (because fragments were too thin or too short), or when anatomical features were not observable due to strong alteration processes (collapsed cell walls, vitrification, presence of radial cracks, among others). In small gauge /diameter fragments it is sometimes difficult to achieve taxonomic identification because some of the characteristic anatomical features of each taxon might not be completely developed (especially when a great portion of the transverse section correspond to the pith and there was not enough woody tissue to examine). Fragments presenting wood knots, or

“compression” and “tension” wood can also difficult the identification due to the alterations in the wood grain.

Following Solari and Lehnebach (2004), identified, unknown, and unidentifiable fragments are expressed in terms of frequency rather than weight or volume. This allows comparison with different size assemblages (of previous or future studies), and it has been proposed as ideal to observe vegetal taxa variation through time.

6.4.3 Taphonomy

Taphonomic features have been used to address social practices related to wood collection and hearth management, combustion itself, as well as depositional and post-depositional processes (Allué, Euba & Solé 2009, Théry-Parisot, Chabal & Chrzavzez 2010). In order to stablish correlation between certain alterations, taphonomic features, and specific issues such as the use and combustion of dead wood, local reference datasets are needed, which to date are non-existent in Southern Chile. Although the focus of the wood charcoal analysis of this project is the taxonomical identification, the main processes altering cell structure were registered using different markers or indicators such as vitrification, radial cracks, xylophage organisms, infillings, and structural collapse. Some of these indicators could be registered using different scales or degrees of alteration (Henry & Théry-Parisot 2014,

Marguerie & Hunot 2007), but in this study they were addressed in terms of presence and absence.

Vitrification, radial cracks or fissures are microanatomical alterations induced by the combustion process (Vidal-Matutano *et al.* 2020). The term vitrification is used to refer to wood charcoal with a vitreous or glassy appearance due to the fusion of cell elements (figure 8), that can vary from partial fusion of cell structure to a dense vesicular glass (Courty, Allue & Henry 2020). Although there is still no complete clarity about under what specific conditions vitrification might occur, it is usually understood as a combustion deformation process where a series of factors need to be considered (McParland *et al*. 2010). According to Arranz-Otegui (2017), water flotation could also bias the representation of vitrified fragments, and it should be considered when evaluating the prevalence of vitrification over other taphonomic features.

Fissures, radial or shrinkage cracks are produced during the first stage of combustion, due to a sudden release of gases and water steam from wood cells. These cracks were traditionally associated with the combustion of green wood, which could present abundance of cracks because of the higher water content in relation to dry wood (Allué, Euba & Solé 2009). Nevertheless, experimental approaches on specific taxa have proposed that radial cracks might not necessarily indicate use of green wood (Caruso-Fermé *et al.* 2017, Théry-Parisot & Henry 2012). In terms of geographic proximity and vegetation similarity, the study of Caruso-Fermé and collaborators (2012) is the closer charcoal taphonomy study done in South America, but since only two native

taxa were studied, there is still a lack of knowledge considering the wide variety of woody species identified at archaeological sites.

The presence of fungal and xylophage organisms has been considered by previous studies as indicators of wood decay (Allué, Euba & Solé 2009, Vidal-Matutano, Henry & Théry-Parisot 2017). However, sometimes differences among living trees and dead wood attacked by fungi or colonized by xylophage insects cannot be easily identify, and not in all the environmental contexts is possible to assume that deadwood correspond to decay wood. At the same time, charcoal from archaeological sites can be infected by modern fungal hyphae either prior to the excavation (Moskal-del Hoyo, Wachowiak & Blanchette 2010). There are no previous studies to establish dead wood or decay parameters for the study region, nevertheless, analysis in the Argentinian Patagonia have suggested that a whitish colour of the mycelia could inform if the wood was infested prior to the carbonization (Caruso-Fermé 2012).

Structural collapse or cell collapse can be described as an irregular contraction of the cellular walls. There might be more than one process that can be linked with this alteration, according to Allué and collaborators (2009), in conifers cell collapse can be registered more frequently in late wood (where fibres are more fragile), and it could be an indicator of the wood state (including growing conditions) and/or the burning process. Cell collapse has also been reported in relation fungal degradation patterns (Vidal-Matutano *et al.* 2021).

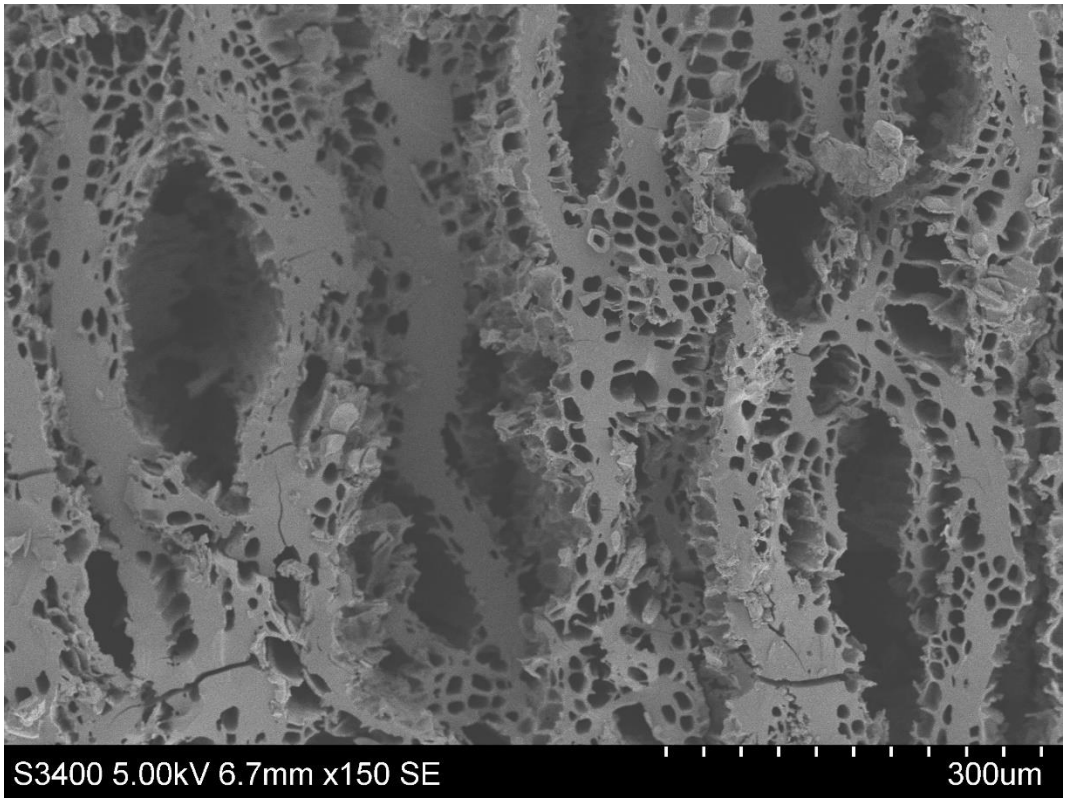


Figure 8 : Wood charcoal fragment from the P29-1 site showing vitrification and radial cracks.

Infillings can reflect either the state of wood prior to carbonization or post depositional conditions. Certain types of wood accumulate different mineral crystal over their life-time in their cellular structure (Carlquist 1989), but also they can accumulate under some conditions, like precipitation related to diagenesis processes in cave environments (Hansen 2001).

Chapter 7: Mocha Island

7.1 Geographical, Ecological and Archaeological Context

The island is located in the South Pacific Ocean (38°22’ S) only 30 km off the coast of Southern Chile. On a clear sky day, the island is visible to the naked eye from the continental coast in front. Geomorphological studies indicates that the island emerged during the Pleistocene due to an abrupt tectonic uplift, and it was probably completely exposed by the end of this period (Prieto 1997). There is no certainty if the island was connected to the mainland in the past, but it has been an insular territory since at least 4000 BCE / 6000 BP, after the stabilization of the sea level (Campbell 2015).

For the last 6000 years, the island has experienced rapid rates of tectonic uplifting (Nelson & Manley 1992), and today the Island has an area of around 50 km^2. The central part of the Island corresponds to elevated Pleistocene marine platforms of around 340 m ASL covered by native forest confined within a Nature Reserve (*Reserva Nacional Isla Mocha*). The central range is surrounded by Holocene marine terraces, that concentrate the modern population settlements as well the archaeological sites (Campbell & Pfeiffer 2017).

The island hosts more than a hundred bird species but in comparison, there are few native species of terrestrial vertebrates including only amphibian, reptiles and rodents (Pefaur & Yáñez 1980). These terrestrial vertebrates could represent relict populations possibly from when the island was connected to

the continent, or they could have arrived by marine drift, since they are of small size (Jackson *et al.* 2013). Although the fauna shows evidence of isolation, a migration flow would have impeded the development of more isolated species. Only two endemic species are recognized: *Eupsophus insularis* (amphibian) and *Octodon pacificus* (rodent).

The vegetation of Mocha Island has been described as a lauriphyllous temperate coastal forest dominated by *Aextoxicon punctatum* (Luebert & Pliscoff 2006, p. 162-163). This type of forest is similar to the one found in the western slope of the Nahuelbuta Coastal range (Biobío and Araucanía regions), but because of the geographic isolation of the Island there are significant differences. The absence of conifers and the *Nothofagus* genus on the Island is one of the most noticeable, since both are quite abundant on the mainland (LeQuesne, Villagrán & Villa 1999). The forest of the Island is believed to be a remnant of the vegetation that existed in the continental coastal region before the diversification of the associations observed today in the evergreen forest of Southern Chile (Villagrán & Armesto 1980). Unfortunately, the available pollen evidence from two stratigraphic lake columns from the Island seems to be not deep enough, and only one ^{14}C date was obtained from it. The base layer from one of the pollen columns was dated to 1760±80 BP/ 300 CE (LeQuesne, Villagrán & Villa 1999). This date is contemporary to some of the archaeological sites of the Island, so there is not available pollen record dated prior to the human inhabitation of the Island.

The pollen record shows an interruption of the *Aextoxicon punctatum* forest development after the 300 CE, when the preponderance of secondary woody

taxa (*Drimys wintery* and *Azara* types) along with herbaceous and palustrine taxa indicates a substitution of the original forest. The pollen data suggest the development of different wet phases during the last 2000 years, which is also supported from Late Holocene terrestrial and fresh-water mollusc records from Mocha Island (Jackson *et al.* 2013). As a whole, this evidence suggests the development of azonal lagoons or water saturated areas.

Besides from the particular ecology of the Island, the cultural history is also different from the mainland. There were no Spanish settlements in Mocha Island, and it was depopulated during most of the Colonial and Historic Period (figure 9). In order to give an appropriate context to the research, the archaeological, historical and ecological information is presented in chronological order using three main blocks: the archaeological evidence during the pre-Hispanic period (1450 cal. BCE – 1687 CE), the European contact and Historical descriptions until the forced depopulation (1544-1687 CE), and the repopulation until nowadays (1840 CE-present day).

ARCHAEOLOGICAL PERIODS IN MOCHA ISLAND (1500 BCE – 1687 CE)

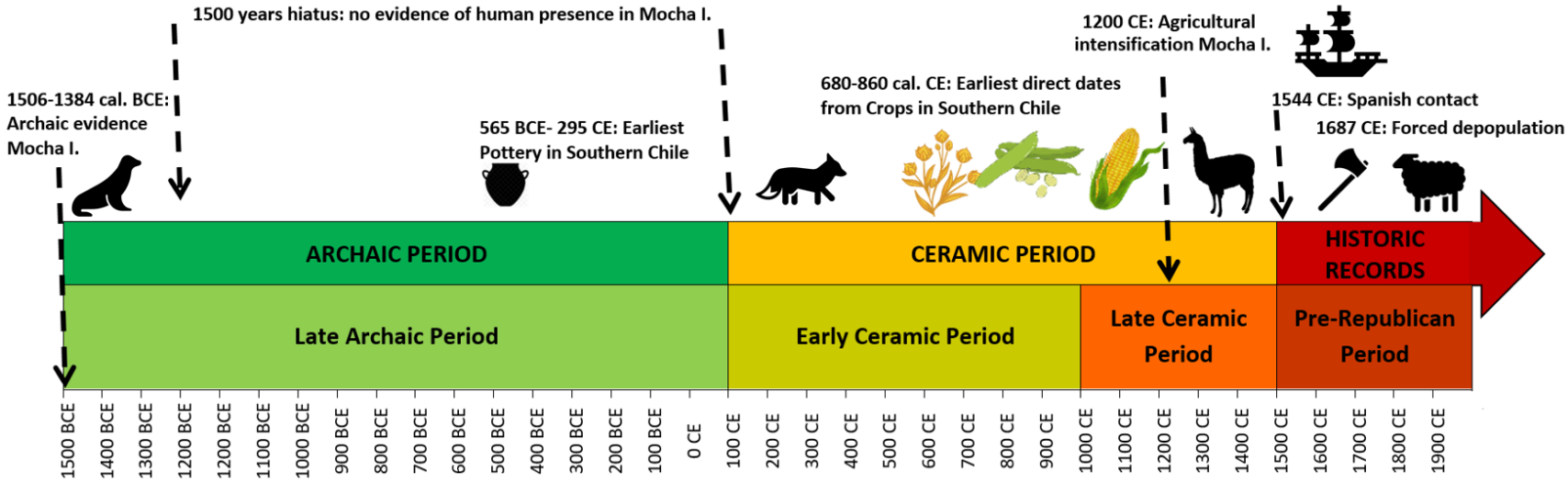


Figure 9: Chronology of Mocha Island

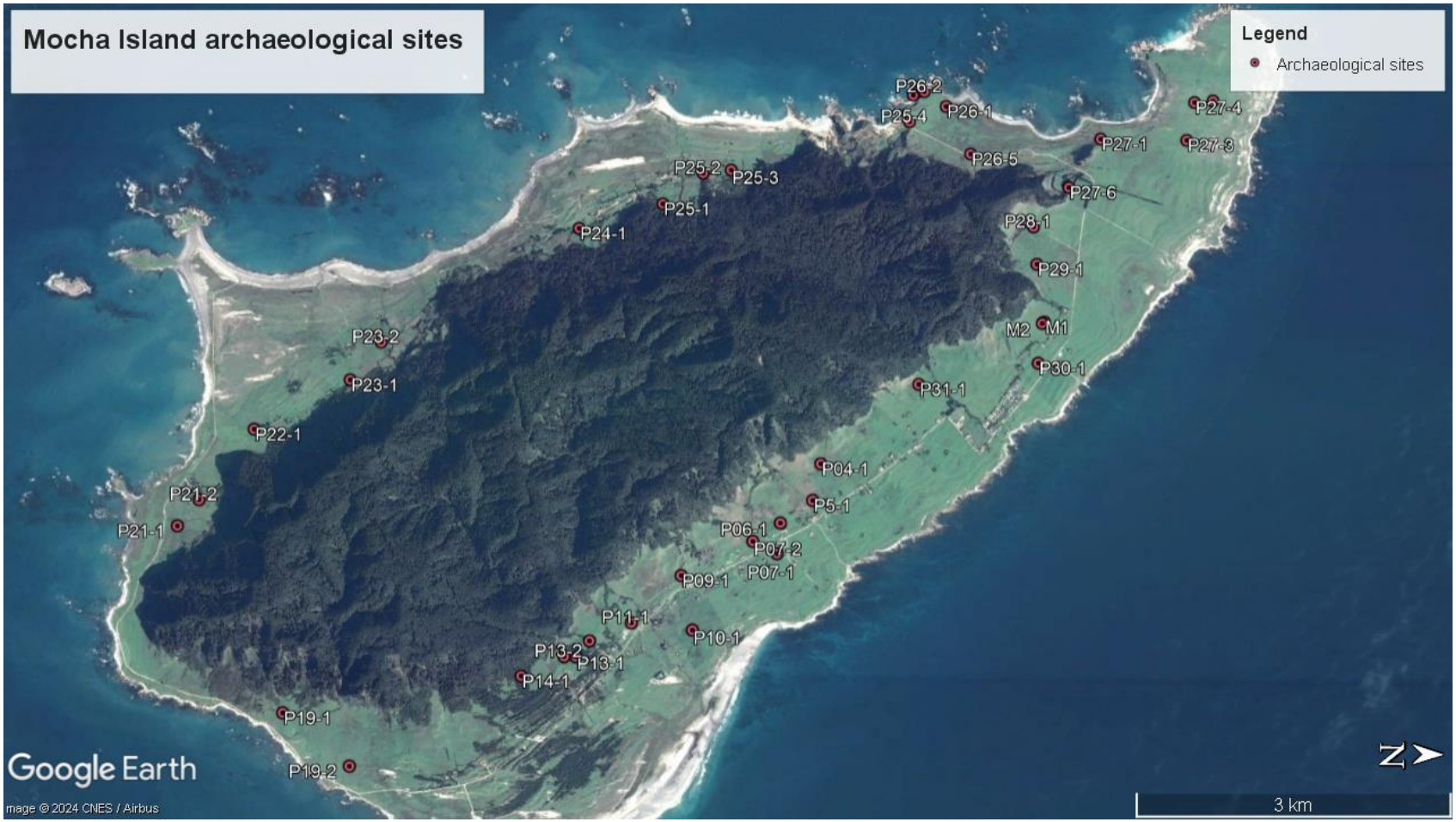


Figure 10: Mocha Island Archaeological sites (2016 Satellite imagery, Google Earth).

7.1.1 Pre-Hispanic archaeological evidence in Mocha Island (1450 cal. BCE to 1544 CE)

Since 1990, there have been a series of archaeological research projects in the Island. Over these years of research more than 20 archaeological sites have been registered (Campbell 2020), and Mocha Island has become a well-studied area in archaeological terms (figure 10), especially for such a small territory. Apart, maybe, from Monte Verde, Mocha Island concentrates the larger number of ^{14}C dates in Southern Chile (n=97), obtained from twelve archaeological sites (table 4). From 2010 onwards, systematic archeobotanical sampling was implemented and most of the available archaeobotanical data comes from the Late Ceramic Sites of the Island. The imbalance of archaeobotanical data can also be observed in the Island date set, were there has been a tendency or predilection to date faunal remains (camelids particularly), in contrast with few direct taxon dates of vegetal remains (for the Late Ceramic Period only).

The earliest human inhabitation in the Island has been dated to the Late Archaic Period of the Southern Chile Archaeological Chronology. This evidence is considered late when comparing to the archaeological sequence of the mainland, where there are sites dated since the Early Archaic Period in the Puren-Lumaco Valley and since the Middle Archaic Period in the Coast of Arauco (Campbell & Quiroz 2015). Because of this late timing, all archaeological evidence of the Island also implies the use of navigation technologies. As mentioned earlier, Mocha Island became an insular territory

with certainty after the Holocene Marine transgression around 4000 BCE / 6000 BP (Campbell 2015).

Table 4: Archaeological sites of Mocha Island.

Site	Extension (ha)	Period	C14 Cal dates-range CE*	N° C14 dates
P5-1	15	ECP?-LCP	651 to 1456	18
P10-1	-	ECP	933 to 946	2
P12-1	5	LCP	804 to 1465	8
P21-1	5	ECP-LCP	1166 to 1599	8
P22-1	4	ECP-LCP	864 to 1477	8
P23-2	5	LCP	989 to 1751	6
P25-1	9	ECP -LCP	103 to 1707	20
P27-1	0,16	AP	-1493 to -1384	3
P29-1	8	LCP	988 to 1342	7
P30-1	-	AP	-1553 to -1454	4
P31-1	14	LCP	1227 to 1563	16
Platform and Mounds	13	LCP	994 to 1861	2

* Dates copied as published by Campbell & Pfeifer 2017 and Campbell *et al*. 2020.

There are two dated Archaic sites in Mocha Island (P30-1 and P27-1), indicating an occupation around the 1450 cal. BCE /3400 cal. BP (Campbell 2015). The artefactual assemblage of these occupations shows an expedient toolkit, which does not resemble the one registered at that same period in the

continental territory right in front of the Island. It has been suggested that these Archaic sites of Mocha Island could correspond to explorations of marine hunter-gatherers from the Reloncaví and Chiloé areas areas (Campbell & Quiroz 2015), who dominated navigation technologies since the Middle Holocene, approximately 4000 BCE / 6000 BP (Rebolledo *et al.* 2021).

The faunal remains of these archaic sites are interesting because it evidences consumption of terrestrial vertebrates, birds and marine vertebrates (Becker 1997). Among the terrestrial vertebrates, there is evidence of small deer (*Pudu puda*) and nutria or *coipo* (*Myocastor coypus*). Assuming the absence of native medium to large terrestrial vertebrates, this evidence indicate that these groups brought deer and nutria to the island, which suggest intentional transportation or translocation (Campbell 2015). Is also relevant to mention that the only complete skeletons recovered from these contexts correspond to sea lion (*Otaria* sp.), which could be interpreted as the consumption of a local insular resource in contraposition to the exogenous terrestrial vertebrates.

After these Archaic occupations, there is a 1500-year hiatus with no evidence of human presence until the Early Ceramic Period (hereafter abbreviated as ECP, approximately 100 cal. CE). The Early Ceramic evidence of the island was registered in five sites: P5-1, P10-1, P21-1, P22-1, and P25-1. The most diagnostic element of these contexts is the pottery, from which ten TL dates were obtained. In addition, eight more C14 dates from the same sites gave a temporal range of the ECP in the Island from the 100 to the 980 cal. CE (Campbell et al. 2020, Sánchez 1997). The charcoal peak registered in the

pollen stratigraphic column dated around the 300 CE / 1760 BP has been interpreted as a burning event of the ECP groups, who would have burn part of the forest in order to obtain clear lands to live and cultivate (LeQuesne, Villagrán & Villa 1999). Although there is not much archaeobotanical information available for this period, *Chenopodium quinoa* was recovered in archaeological layers dated to the ECP (Sánchez, Quiroz & Massone 2004).

Like the Archaic Period, the faunal remains from the ECP evidence the consumption of local animals but also the intentional transportation or translocation of medium to large terrestrial vertebrates (Campbell & Martínez 2017). For the period there is evidence of camelids (Camelidae), small deer (*Pudu puda*), nutria or *coipo* (*M. coypus*), fox (*Pseudolapex* sp.), wildcat (*Oncifelis* sp.), and grison (*Galictis* sp., Goicovich & Quiroz 2008).

It is still uncertain if the ECP groups who inhabited Mocha Island did it permanently, seasonally or sporadically, but it is believed that the sites were continuously inhabited since the Early Ceramic Period until the Late Ceramic Period and Historic Period (hereafter abbreviated as ECP, LCP and HP respectively). Although these sites have been described as domestic contexts, human remains were recovered in most of them. A well-preserved single individual recovered from the P21-1 showed the diagnostic ECP crouched inhumation pattern (Goicovich & Quiroz 2008, p. 44-47). The only funerary site denominated as such is P10-1, where remains from at least eleven individuals were recovered from a collective burial that showed disturbance. Also, this the only ECP site that does not have a later LCP component (Sánchez 1997).

Isotopic data from two individuals from the P-10 site indicate a mixed diet that included terrestrial and marine resources (Campbell *et al.* 2020).

The archaeological contexts ascribed to the Late Ceramic Period (from 1000 CE), correspond to dense habitational deposits showing an intensive and reiterative use of the space that suggests continuity until the depopulation of the Island (1687 CE). Although the end of the LCP has been established at the time of the European contact (1554 CE), in stratigraphic terms is almost impossible to distinguish the LCP from the HP. The archaeological data as well as the written records indicate the absence of European historical settlements in the Island, and following the previous publications (Goicovich & Quiroz 2008, Campbell 2020) the post contact archaeological evidence will be considered as a continuum of the LCP, since the native population kept inhabiting the same residential units /archaeological sites until the forced depopulation.

In comparison to the previous Periods, the LCP sites are the most ubiquitous archaeological contexts in the Island, and their extension varies between four to fifteen hectares. As well as in the mainland, the Island's sites extension has been interpreted in relation to population growth and a sedentary settlement pattern (Campbell 2020). The excavations at eight habitational contexts ascribed to the LCP have provided 82 ^{14}C dates from 100 CE to the 17th century. In terms of spatial and social organization, each of these sites has been studied as a domestic unit. In addition to the domestic sites, two C^{14} dates from a mound-and-platform complex situate the construction of public architecture in the Island from the 1000 CE (Campbell & Pfeiffer 2017). The

mound and platform complexes are not linked to a particular site and its construction would have involved an amount of work that most likely exceeded the capacity of a single domestic unit. This complex has been understood as a public space of social aggregation product of collective or collaborative work (Campbell 2020).

The ceramic assemblage of this period shows not only changes in the decoration patterns from the ECP, but also a significant increase in size and thickness indicating the existence of big ceramic containers. Starch analysis conducted in a small sample of ceramic sherds suggests the preparation of fermented drinks, such as *muday* or *chicha*, made of maize (*Zea mays*) and the *maqui* berry (*Aristotelia chilensis,* Godoy-Aguirre 2018). Altogether, this evidence has been interpreted in relation to the existence social gathering activities that required the accumulation and storage of food and beverages (Roa, Silva & Campbell 2014, Roa *et al.* 2018).

The archaeobotanical record of the LCP includes evidence from macro botanical remains (charred seeds and wood charcoal analysis) as well as micro botanical remains (starch and phytoliths studies). Although for most of the sites we only have data from carpological/ charred seeds analysis, the integration of all the archaeobotanical data from the different sites indicates the presence of more than 50 plant taxa during this period (table 3, appendix A). Among the identified taxa there are cultivated plants (clearly introduced to the island), as well as native plants with known economic or ethnobotanical value (Roa *et al.* 2018, 2021). The taxa commonly found in all the considered sites are

Chenopodium quinoa (quinoa), *Aristotelia chilensis* (maqui berry), *Zea mays* (maize), *Rubus* cf. (wild raspberry), *Chenopodium* sp. (indeterminate *Chenopodium*), Cyperaceae (indeterminate Cyperaceae), and Fabaceae and cf. Fabaceae (indeterminate legumes). Among the cultivated taxa, *C. quinoa* always shows a high ubiquity in all sites (over 50%), while maize showed a variable ubiquity, and the legumes show a low one (Roa *et al.* 2021). Other crops such as the common bean (*Phaseolus vulgaris*), and grasses (such as *Bromus* spp. and indeterminate Poaceae) were found in les sites and they show variable to low ubiquities. Among the wild plants, berries such as *Aristotelia chilensis, Rubus* cf. *geoides*, *Fragaria chiloensis,* and *Ugni* spp. are the most ubiquitous. The ripe berries of these taxa are traditionally collected during summer or early autumn (Godoy 2008), and although the ubiquity and frequency values vary for the different taxa, altogether their representation in the archaeobotanical record is constant and suggests its possible desiccation and storage (Roa *et al.* 2021).

In relation the chronology of crops, it was initially proposed that quinoa was introduced earlier than maize, during the ECP. Maize was then introduced later, during the LCP (Sánchez, Quiroz & Massone 2004). The available taxon dates indicate that maize was present in the Island since 1000 CE, and around 1300 CE maize, beans, and quinoa become ubiquitous in all the sites (Campbell 2020). Although quinoa grains tend to be recovered in deeper layers than other crops, there is usually not enough of them to obtain a ^{14}C date from these layers (about 15 grains of quinoa were used just for one ^{14}C date).

The zooarchaeological evidence indicates the consumption of terrestrial and marine vertebrates, birds, fish, and molluscs (Campbell 2020). More than 40 different taxa have been identified in the assemblages from the Island, but there is a clear preference for camelid consumption (Roa *et al.* 2018). Among the terrestrial vertebrates, the presence of *Pudu puda*, Carnivora and Camelidae has been interpreted as evidence of intentional transport or breeding within the island (Campbell & Martínez 2017). These taxa have been recovered since the earlier periods, but it is unclear if they correspond to populations of previously introduced animals that were able to establish and reproduce in the island, or to different translocation/transportation events. Based on the evidence of one of the sites where a high mortality among young camelids was registered (P31-1), it has been proposed that camelids were brought from the mainland being very young because it would have facilitated their transport but some of them would have die during the taming process (Goicovich & Quiroz 2008, P. 43-44).

The archaeological information suggests that the Mocha Island population consumed cultivated as well as wild plant resources, along with terrestrial and marine animal resources. This diet goes in accordance with the proposed mixed economy of the Late Ceramic Period that combines the production of resources (management of animals and cultivation of plants) with the use of wild resources (foraging, hunting, and fishing). Clear evidence of agricultural fields or cultivation areas has not been identified in the Island, but the recovery of shovels made of Cetaceae bones suggests the use of artefacts for agricultural purposes Becker 1997). In addition to the faunal remains, the lithic

artefacts also provided evidence indicating hunting and fishing activities (fishing weights), and though the use of firewood and timber resources is detailed in a following section, it is argued that the lithic assemblage indicates the work of wood also (Jackson 1997).

Although the zooarchaeological record shows a predilection for camelids, the isotopic values indicate a mixed diet of marine and terrestrial animals and plant resources (Campbell *et al*. 2020, Montalvo-Cabrera *et al.* 2024). Is also interesting that some of plants and animal remains sampled for Isotopes during this Period show high ^{15}N values that could suggest the use of fertilizers in the case of the plants, and the ingestion of these enriched plant resources as well as seaweed in the case of the animals (Campbell *et al*. 2020). More recent organic residue analysis indicates that pottery sherds were mainly used for C_3 plants (such as *Chenopodium quinoa*) and marine resources, suggesting that maize could have been consumed as fermented drinks rather than as a staple food. In relation to camelids, its importance as a protein source was not dismissed because there might have been different cooking practices such as roasting or drying that did not involve the use of pottery sherds (Montalvo-Cabrera *et al.* 2024).

In terms of social and economic organization, the studies in Mocha Island suggest that each of the main sites / domestic units were autonomous in terms of subsistence. The lithic assemblage of the LCP shows an expedient and multifunctional toolkit with a marked preference for local rocks (Campbell, Stern & Peñaloza 2017). The stone tools evidence the exploitation and processing of

wood, as well as other plant and animal resources (fish, molluscs, marine mammals, and fish). In minor proportion, exogenous lithic materials such as obsidian and siliceous rocks were also found in the Archaeological record of the Island. In addition to them, the presence of other exogenous materials such turquoise and metallic ornaments in the sites indicates that the LCP population of Mocha Island participated in interaction networks that allow them to obtain materials and/or objects with a provenance as far as 350 km (Campbell *et al.* 2018). Although there is no evidence of wealth accumulation, these foreign good were interpreted as prestige artefacts involved in social differentiation displays connected with an intensification of the social and exchange networks from around the 1000 CE (Campbell, Stern & Peñaloza 2017).

The population of Mocha Island keep in contact with the mainland, and it is likely that as part of their social interaction network they also received visitors from the mainland. After 1544 CE, European Navigators who traded goods for food and fresh water visited the Island. Although there are not sites indicating a European settlement in the Island and the Historic European artefacts are scarce in the archaeological record, some glass beads recovered in a burial from the P21-1 site are evidence of this exchange (Goicovich & Quiroz 2008, p. 39 and 59). According to the historical records (which are discussed on the next section), the population of Mocha Island incorporated sheep before the island was depopulated. Although bones identified as *Ovis/Capra* were recovered from the upper layers of some of the sites (Roa *et al.* 2021), there are no direct dates for old word taxa and they could also correspond to more recent remains.

Finally, it is important to mention that no direct archaeological evidence of navigation has been recovered in the Island such as boats or oars. The ethnographic evidence of Southern Chile and the Patagonian Channels suggest that the navigation objects would have been made of perishable material such as wood and vegetal fibres, which are unlike to preserve unless charred. Nevertheless, the analysis on human remains from the ECP to the LCP indicates that rowing was an activity frequent enough to cause noticeable muscular insertions in the humerus as well as bone pathologies in the arms and scapula (Constantinescu 1997). Also, and although in small proportions, some of the identified fish, such as *Carcharhinus* sp. (shark), *Genypterus chilensis* (*congrio*) and *Callorhynchus callorhynchus* (*pejegallo*), imply offshore fishing practices (Goicovich & Quiroz 2008, Roa *et al.* 2021).

7.1.2 European contact and forced depopulation of the Island (1544-1687 CE)

The first European expedition to the Island was led by Juan Bautista Pastene in 1544 CE. Allegedly, Gerónimo de Bibar was also part of that crew and in his chronicle, he mentions that there were more than 800 people in the Island. The islanders prohibited the Spaniards to go deeper into the island, but they could not impede an attack that killed fourteen islanders. The Spaniards took two islanders as prisoners and loaded their ship with maize, potatoes and beans ("maíz, papas y frisoles, que había gran cantidad" Bibar, 1966, p. 148). Bibar also mentions that the Mocha people were the most well stocked natives and with the best houses he had ever seen, which was due to the fertile soil of the Island ("*no he visto indios más proveidos de bastimiento y de mejores casas que en esta isla, mas no es de maravillar porque es muy fértil tierra*" Bibar, 1966, p. 149).

After this first encounter, it is not surprising that the Mocha people did not allow any more Spanish ships to land on the Island. From the Spanish point of view, the Islanders were depicted as the most bellicose people who moved from the mainland as consequence of the Spanish advances on the mainland (Goicovich & Quiroz 2008, p.122-123). During the following years, different European expeditions landed on the Island. Because the island was not properly incorporated to the Spanish territory, Dutch and British ships were able to obtain water and food in exchange for iron knifes and other goods.

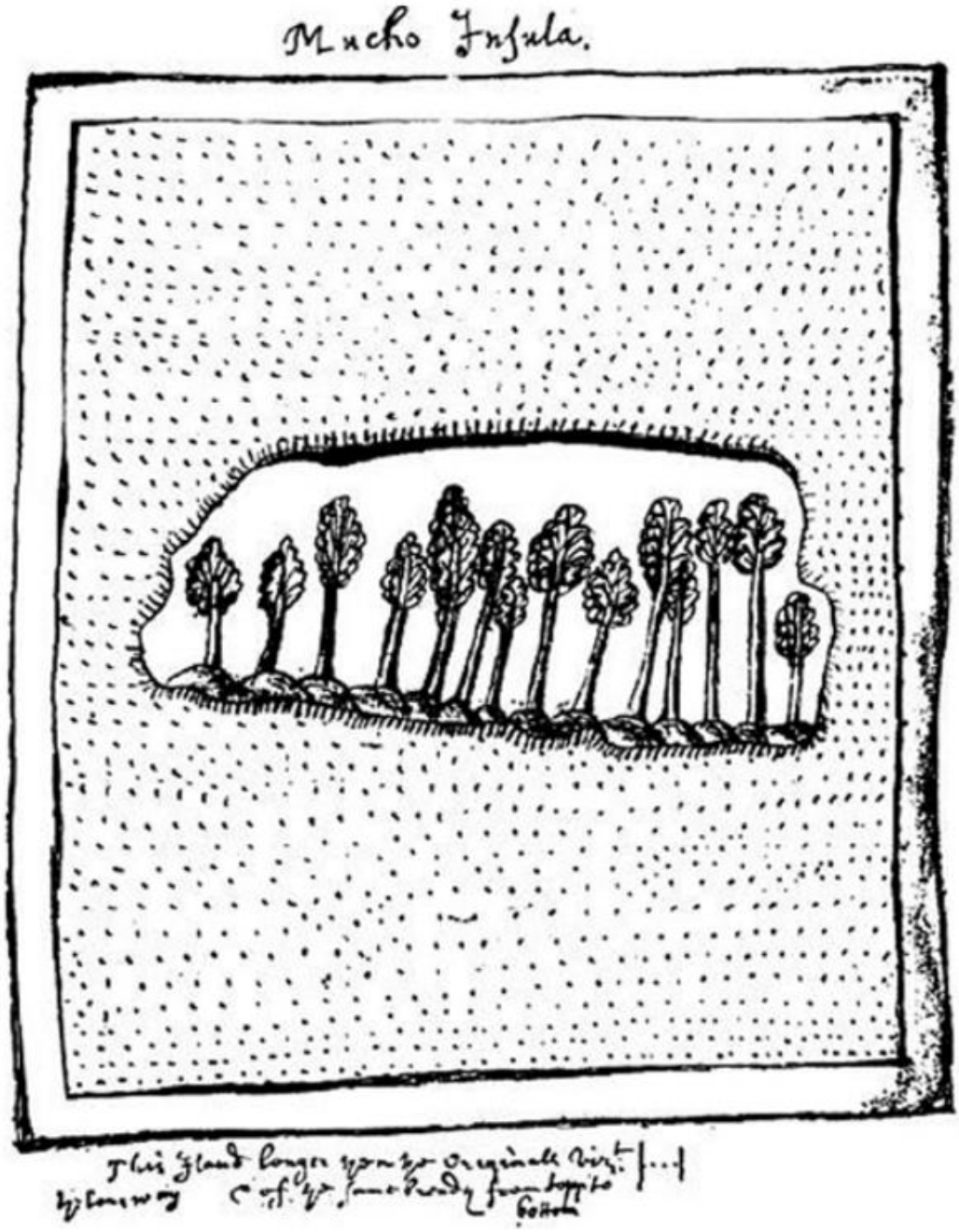


Figure 11: Sloane Manuscript n°61 (Roa & Iglesias 2017).

In 1578 CE, the English expedition lead by Francis Drake arrived on Mocha Island. According to the notes by Fletcher (1652), and other members of the expedition (Pretty 1910), the Island was well populated, and the people kept

sheep and "*other cattell, maize, which is a kinde of graine whereof they make bread, potatoes, with such other rootes"* (Flecther 1652, p. 47). Although on the first day the English navigators obtained fruits, two fat sheep, potatoes and roots, during the second day the islanders fought the captain and part of the crew because someone used the Spanish word for water (*agua/aqua*) making the locals believe that they were actually Spaniards pretending to be English. Fletcher mentions that around 500 well-armed men fought the English, and as a result part of the crew was badly injured. Another source of this voyage is Manuscript N°61 of the Sloane Manuscript Collection (copied in 1677) which correspond to notes and one engraving made by Fletcher (figure 11, Roa & Iglesias 2017). In addition to the previous sources, the manuscript mentions "*hens and bowes arrows and darts made of canes*" (Quiroz 1997).

There are two more documented British expeditions, one in 1587 led by Thomas Cavendish and the other in 1594 led by Richard Hawkins. Mocha Island was not well described on the records from 1587 expedition. From the notes on the 1594 expedition, we know that the Mocha Islanders kept a bellicose reputation after the encounter with Drake himself and his crew. Accodring to Hawkins, the Mocha people had "*sheepe, Cockes, &c. (from Hennes they would not part), divers sorts of fruits and rootes, which they exchanged with vs for Kniues, Gglasses, Combes, Belles, Beades, Counters, Pinnes, and other trifles" (*Hawkins 1933, p. 98*).* The testimony mentions sheep (good and fat ones from the breed introduced to the mainland by the Spaniards), and also the "sheepe of the Country". In relation to the last one, Hawkins states "*we could by no meanes procure any one, although we saw of*

them, and vsed meanes to haue had of them; for they esteem them much" (1933, p. 99). The testimony also mentions that the islanders wore clothes made of wool, and that they built round houses "*like unto ovr Pigeon houses, with a laver in the top toppe to evacuate the smoake when they make fire"* (1933, p. 146).

In relation to the Hawkins expedition, a Spanish document of 1597 mentions with serious concern that the rebellious islanders provided to the English expedition firewood, water, cattle, chickens (*gallinas*), and other provisions and food (Goicovich & Quiroz 2008, p. 116). In the eyes of the Spanish authorities, the exchanges between the islanders and the European enemies of the Spanish crown had to be stopped before any alliance could be formed.

Later descriptive narrations of the Mocha Island come from two Dutch Expeditions: the 1600 expedition lead by Olivier van Noorth and the 1615 expedition lead by Jaris van Spilbergen. There were other Dutch expeditions known to land on the Island, but their descriptions were succinct. According to the diary of Van Noort, the Dutch navigators decided to land in the island because they saw a well ploughed land with many sheep and animals grazing (Van Meurs 1993). In exchange for each sheep, the islanders obtained one axe, and for one or sometimes two chickens, they could get a knife. The diary also mentions that the Mocha Islanders valued iron tools because they could exchange them in the mainland. The Dutch navigators were able to obtain maize, potatoes, squash and other fruits, and on the second day the crew was invited to visit where the islanders lived, a town with around fifty huts made of straw *("daer een Dorp stont van ontrent vijftich huysen, welck van stroo*

ghemaeckt zijn, ende van fantsoen lanckwerpich, met een Portael int midden," van Noort 1602, p. 32). They drank "Cice", a drink made of maize, and they describe big sheep or *groote Schapen* with long neck and with long wool that almost touches the floor ("*van groote Schapen. Dese voorseyde Schapen hebben seer langhe halsen, ende de Wol is hem so lang datse bycants aen de aerde hanght*" Van Noort 1962, p.32). The diary also mentions that the wool of these sheep was used to make the clothes of the Mocha people, and that the Dutch were not able to procure any of these big sheep, only the other sheep alike the ones in their homeland, but very fat and beautiful.

The Van Noort diary also contains two illustrations (figures 12 and 13). Since at that time it was common that people who did not necessarily participate in the expedition the created images, they should be examined with caution (Van Meurs 1993). For instance, the big sheep that seems to be camelids are shown with a hump on the back like a camel (figure 12), but the diary never mentions this detail. There are also no descriptions of the types of trees of the Island but on the second image, we can see a palm like plant (figure 13), which according to pollen and vegetation descriptions seems unlikely. There is another version the images on Van Noort diary that was publish in 1602 by De Bry (Acosta et al. 1602), as part of a compilation of different expeditions. In this image (figure 14) a combination of the elements of both Van Noort engraving is observed: the background is similar to figure 12, but the three people from the figure 13 were also incorporated.

The information from the 1615 expedition comes from Speilbergen's Journal (De Villiers 1906). According to the testimony, the islanders were waiting on the shore with "many kinds of provisions- such as sheep, fowls, and other poultry" and the navigators exchanged "hatches, beads and other trifles for a large number of sheep" (1906, p. 52), which again are mentioned to be very large and fat. Unlike the previous expedition records, they also managed to take on board "a sheep of a very wonderful shape, having a very long neck and a hump like a camel, a hare lip and very long legs" (1906, p. 53). The journal also mentions that they employed these sheep to till their land, and there is an image where they show the sheep of "strange shape" (figure 15, detail L). Is noticeable that vegetal resources are barely mentioned as fruit in letter B of the image description. There is another version of the image published by Johann-Theodore de Bry (Schouten, Dantiscanus & Bry, De 2002), and where there are also subtle changes in the image descriptions since is written non using the testimonial first person point of view as in Speilbergen's Journal (figure 16).

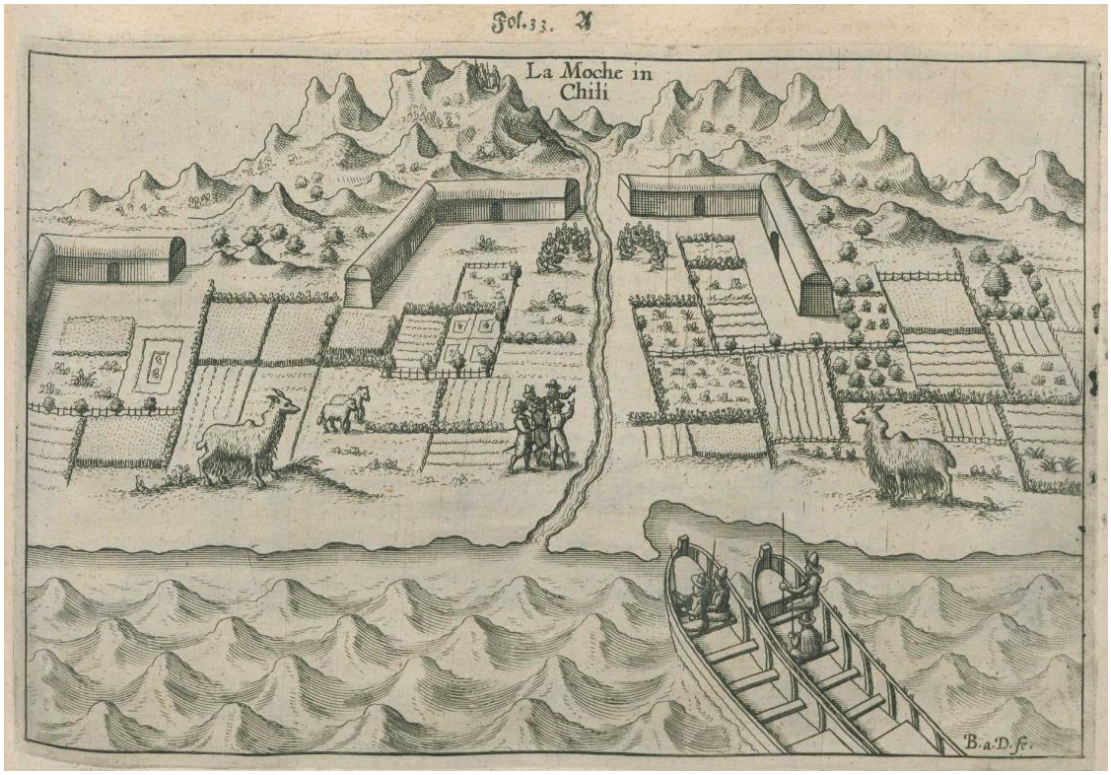


Figure 12: Van Noort, 1602.



Figure 13: Van Noort, 1602.

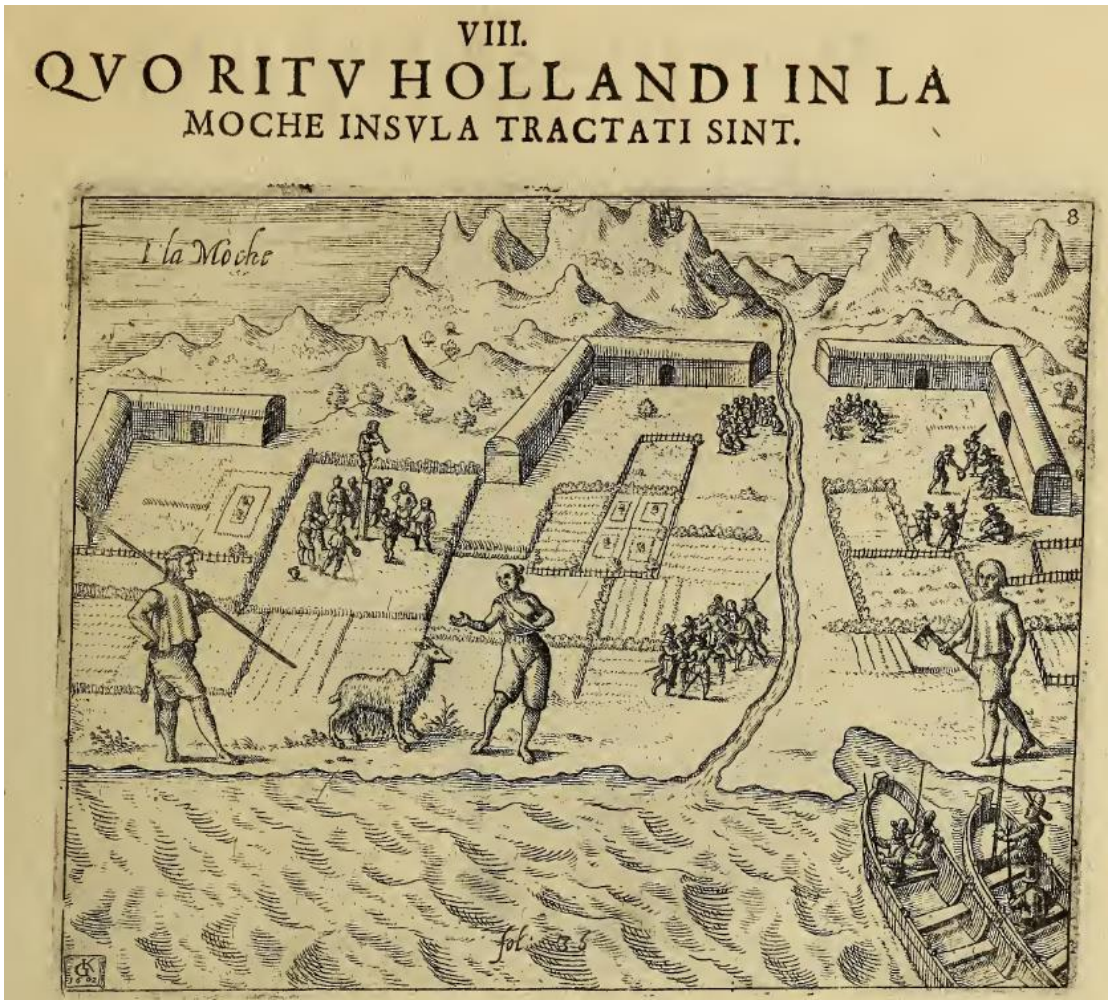


Figure 14: Bry, Johan Theodor de, and Johan Israel de Bry 1602 (Acosta et al. 1602).



Figure 15: Plate n°4 and description from Speilbergen's Journal: N°4 is the Island of Mocha. With the explanations as shown under A, B, C.

A. Are our boats in which we rowed ashore to trade with them.
B. Is the manner in which we traded with the people of La Mocha, exchanging hatchets and knives for sheep, fowls, and fruit.
C. Is the manner of sitting with their legs cross-wise, like the tailors sit in Christian countries.
D. Is the manner in which our trumpeters and other musicians gave a grand concert on the beach.
E. Are the La Mochayanes who listened to that playing with great pleasure.
F. Are their houses or huts, into which they would not let our comrades come.
G. Is the manner in which they bring along their sheep and other commodities to barter them.
H. Was our yacht, which lay close to the shore.
I. Are our four other ships, with which the boats kept up constant communication.
K. Is their manner of dress or clothing.
L. Is the strange shape of some of their sheep, which have a hump on the back like a camel.

Publication of 1619, in the facsimile of 1906 (de Villiers 1906).



Figure 16: Image and legend from De Bry 1620 (Schouten et al. 2002).

The island of La mocha
A. These are the boats that went to shore.
B. This is the trading carried out between the Hollanders and the barbarians with the exchange of axes and knives for sheep, chickens, and fruits.
C. This is the common manner of seating among them with one bloody form placed over another in the manner of corpses.
D. The horn players and musicians from among the Hollanders come to shore.
E. The people of Mocha enjoy this.
F. The huts from whose entrances they summon the Hollanders to enter.
G. Sheep and other goods brought to trade.
H. One of the Hollanders' ships watching the shore.
I. Four of the Hollanders' ships with their boats passing back and forth.
K. Their clothing
L. The sheep from Gibbosa which look like camels.

From this review of early historical records, we can summarize that at the time of the European Contact, the inhabitants of Mocha Island managed animals and they cultivated the land. In the first testimony by Bibar (1544), old world animals were not mentioned, but from 1578 they are always present, and the sheep are usually admired because of their size and fatness. The strange looking sheep were most likely camelids and seems evident that the Islanders value them more than other animals. Their representation in the archaeological record is also important. It is probable than old world animals were brought to the Island shortly after the arrival of the Spaniards to Southern Chile, and as was mentioned in the previous archaeological section, faunal remains from these animals were recovered in the upper layers of the archaeological sites. Other of the aspects mentioned in these descriptions are the clothes made of wool. No direct archaeological evidence of textiles has been recovered in the island. Nevertheless, traceology analysis of bone artifacts indicates that animal fibres and textiles were elaborated in the Island during the LCP (Inostroza 2019).

In relation to the vegetal resources, the plants mentioned in these documents are maize, potatoes, beans, squash, and other fruits. “Cice” drinking is also mentioned, and most certainly correspond to the fermented *chicha* drink. Old World crops were only mentioned in the Rosale’s chronicle, and in the testimony of Wafer (1903). Rosales indicates that the Island is very fruitful and there is abundance of maize and legumes, but a moderate amount of wheat and barley because is planted less (“*cogen copiosamente maiz y legumbres, y trigo y cebada con moderacion, porque siembran poco de eso*” Rosales 1877,

p. 289). Rosales also gives one of the few descriptions of the raft boats used to cross from Mocha Island to the mainland. According to the Jesuit, during the month of March, when the wind is not so strong, the Mocha people make big raft boats of "*maguey*" where they can fit thirty people and sheep ("*hazen valsas muy grandes de magüeyes, en que pasan treinta personas y traen muchos carneros y otras cosas con que comerciar"* 1877, p. 173). According to Wilhelm de Moësbach (1992), *maguey* is an Antillean term used to refer to the agave plant, which is not native to Southern Chile. Nevertheless, maguey was used as a synonym of *puya* or *chupalla*, which refers to some species of the Bromeliaceae family.

If we do a comparison between the historical and the archaeological record, we notice that certain plants, such as potatoes and squash have not been registered among the archaeobotanical assemblage. Only few seeds of *Solanum* sp. and Solanaceae have been recovered in few sites (Roa *et al.* 2014, Rojas & Cardemil 1995), but they could correspond to other native species. The houses, boats and some artefacts were made of perishable vegetal fibres, so they were less probable to preserve in the wet environment of Southern Chile. According to the ethnobotanical information, the *lin* (*Anthoxanthum gunckelii* (Parodi) Veldkamp) was the preferred grass for the construction of *rukas* or houses (Gumucio 1999). Seeds of Poaceae have been identified in most of the sites (Roa *et al.* 2021), but they could also correspond to other species. In relation to the raft boats allegedly made of *magüey* (Bromeliaceae), few fragments of monocots have been identified in previous

analysis (Delgado 2017), but they could also correspond to canes, which were described to be used as spear handles in the Sloane manuscript (Quiroz 1997).

The Spaniards began the depopulation of the Island in February 1685. A census indicates that the total population of the Island was 588 people (Campbell 2011), although different sources gave different numbers. Jerónimo de Quiroga, the soldier in charge of the operations informs that 800 people were taken from the Island, while other documents indicate 653 souls, and others more than 700 (Goicovich & Quiroz 2008, p. 137-140). The Mocha population was relocated in a reduction named the Mocha Valley, two leagues away from the city of La Concepcion. The depopulation of the Island was completed on 1687, and in order to discourage indigenous people to move back to the Island but also a possible Dutch or English occupation, the Spaniards make sure to set fire to the houses and cultivation fields.

After the depopulation, buccaneers and whalers visited the Island. Among the buccaneers, Edward Davis visited twice, first in 1686 and later in 1687. The description written by Lionel Wafer, an Englishman part of Davis's crew, show two very different panoramas. The first visit was in December 1686, about ten months after the depopulation of the Island started. Wafer mentions that the Island produced maize, "other wheat, barly", a variety of fruits, and the several houses of the "Spanish Indians" were well "stored with Dunghil-Fowl" (1903, s. 180). He also mentions several horses, but what takes most of the description is a "sort of Sheep", called Cornera de Terra (*carnero de tierra).* This sheep is described as a tame creature with long wool, no horns and with a cloven-footed

like a sheep. The testimony stated that they killed forty-three and obtained bezoar-stones from thirteen of them, and that their flesh was like mutton. On their second visit, around the end of the year 1687, they found that “the Spaniards had wholly destroyed or carried away the sheep, horses and all other living creatures” (1903, p. 191).

The island was uninhabited between 1687 and 1840. For around 150 years, ships landed occasionally to get fresh water and animals. According to some of the descriptions, the Island was well known around buccaneers and whalers because of its whales, sea lions, wild horses and pigs (Reiche 1903). One of the most remarkable visitors was Jeremiah N. Reynold, a writer and explorer who wrote about an albino-sperm whale that lived near Mocha Island, which later served as inspiration for Melville’s Moby Dick. As part of an expedition that reached the Antarctic territory, Reynold visited the Mocha Island between 1829-1831 and published the manuscript in 1839. Although the testimony focus is the Mocha dick whale, the brief description of the “entirely deserted” Island mentions a luxurious vegetation (Reynolds 1839, p. 377).

7.1.3 The repopulation of Mocha Island in the 19th century onwards (1840 CE to present)

From 1840 mainland entrepreneurs, mainly dedicated to farming but also to hunt sea lions, occupied the island illegally. Around that time, a shipyard was installed in the Island. In 1852, to stop the illegal exploitation of the Island, the Chilean State decided to rent the Island and regularize its inhabitation. In 1902 Cañas Pinochet visited the Island and described on the central mountains a gigantic secular forest, virgin and impenetrable (*"bosques seculares i jigantescos, vírgenes e impenetrables*" 1902, p. 58). In opposition, he mentions that the plains of the island have been cleared "by man´s hand and fire, the aid of destruction that ignorance has exploited for centuries" ("*La mano del hombre i el fuego, este ausiliar de destruccion que ha esplotado por siglos la ignorancia*)". Cañas Pinochet was clearly a man of his time and described the burning as a battle against the forest ("*lucha contra el bosque*") and indicates that the tallest and wider trees have disappear because of agriculture and logging. Back then, the population was composed of thirty families and the most common crops produced in the Island were potatoes, barley, peas, onions, and fodder (cattle and sheep).

In 1929 the Chilean government decided to create a Colonization Agency for Mocha Island (Caja de Colonización Agrícola), dividing the plain of the Island in 32 allotments or *parcelas*. Instead of renting, each of the families owned their land, and although the main forest is still state-owned ground, each of the *parcelas* had a corresponding patch of forest, as well as direct access to the shoreline.

Over the years, the island has been studied by different specialists, and botanists and naturalists visited the Island, describing its geology and ecology. In vegetation terms, the most relevant reference that gives a detailed account of the botanical species present and absent on the island is the publication of Karl Reiche (1903), which he wrote after a summer visit to the island in 1902. Later, in 1958 there was a “Mocha expedition” during which the botanist G. Kunkel (1968) participated and subsequently added more species to the initial list made by Reiche (especially in relation to lichens and ferns). Both publications were the basis for the later ecological studies (LeQuesne, Villagrán & Villa 1999, Pefaur & Yáñez 1980), and they provide a historical perspective of vegetation changes on the island during the last hundred years.

According to the study of Reiche, the woody taxa of the island is composed by 47 species (detailed list in table 4, appendix A) that include 14 trees, 21 shrubs and/or small trees, and 12 smaller woody and lignified plants (subshrubs, climbing shrubs, parasite shrubs, and canes). The families absent from the Island are Podocarpaceae (and all other native conifers), Nothofagaceae, Proteaceae (with the exception of *G. avellana*), Berberidaceae, and other common species present in the continent such as *Weinmannia trichosperma*, *Lapageria rosea* Ruiz & Pav., *Sophora macrocarpa*, *Sophora cassioides* (Phil.) Sparre, *Boquila trifoliolata* (DC.) Decne., among others. In the posterior study of Kunkel, most of the woody species listed by Reiche were registered, and seven woody species were added (including two trees). As well as Reiche, Kunkel acknowledges the absence of the already mentioned families and species, adding to them *Cryptocarya* (Lauraceae). Also informed the

impoverished status of certain genera such as *Chusquea, Greigia, Eucryphia, Flotowia* (currently named Dasyphyllum), and *Gevuina* (1968). The only species mentioned to be absent by Reiche that was registered by Kunkel is *Lapageria rosea* or *copihue*, a climbing shrub with high ornamental value that could have been reintroduced to the island after Reiche's visit.

According to Péfaur and Yáñez, in 1980 the population of the island was estimated in 700 people, who needed about 1000 grown trees for firewood and timber. In that same year, they inform that *Persea lingue* and *Eucryphia cordifolia* were quite rare, and *Peumus boldus* and *Laurelia sempervirens* were in constant decline because of its exploitation as timber. Later publications mention the presence of few specimens of *Persea lingue*, and complete absence of the Proteacea family (LeQuesne, Villagrán & Villa 1999). Other species mentioned by Reiche and Kunkel, such as *Acacia caven* (Fabaceae*),* were not mentioned at all.

Although in 1990 the population of the island was 860 people, the last national Census of 2017 indicated 419 people (the results from the Census of 2024 were not available when this dissertation was submitted). Along with a decrease in the population, the agriculture and livestock activities have also decreased significantly. From 2013-2015 fieldwork observations in the island, I know that agriculture today is mainly a self-sufficient activity for each family of the Island and doesn't involve mechanized ploughing.

As well as in the pre-Hispanic times, people have continued to introduce not only plants but also animals to Mocha Island. Among the non-native trees the

most common are cypress, and different orchard trees (people had even tried to grow bananas and pineapple with occasional success, but apple trees were the most well adapted to the island). In relation to the animals, the pudú (*Pudu puda*) was extinct from the island during Reiche visit, but it is mentioned to be present in 1980 (Pefaur & Yáñez 1980). According to the islanders, a female and a male specimen were introduced from the mainland years ago, and then released into the forest / reserve. The occasional sighting of these animals indicate that they are still living there. Another noticeable reintroduction is the llama (*Lama glama*). Although is not certain if the pre-Hispanic people kept llamas or guanacos (*Lama guanicoe*), the llamas observed between 2013-2015 were well adapted (figure 17), and according to the islanders they were free to graze and they pretty much managed on their own.



Figure 17: Llamas in Mocha Island (courtesy of Constanza Roa, January 2013).

7.1.4 Studied archaeological sites of Mocha Island

The wood charcoal from two sites of the Island was analysed for this dissertation, the P5-1 and P29-1 sites (figure 18). The name or code of the sites stars with the letter P from the word *parcela* (allotment), then a number (from 1 to 32, because there are 32 *parcelas* in the Island), and then a second number in case there are more than one site registered in a single *parcela.* Following this logic, the P5-1 site is located in the *parcela* number 5 and the P29-1 in the *parcela* 29. Since only one site was registered in each of these *parcelas*, to simplify the nomenclature the sites will be referred just as P5 and P29.

The criteria behind the selection of the sites lies primary on its chronology and availability of materials. Since there were not available archaeobotanical samples from the excavations before 2010, I was only able to work with the sites ascribed to the LCP (because the projects were focused on this period and the excavations were not directed towards the earlier Periods or sites). The samples were selected from the sites with the earliest dates on the LCP.

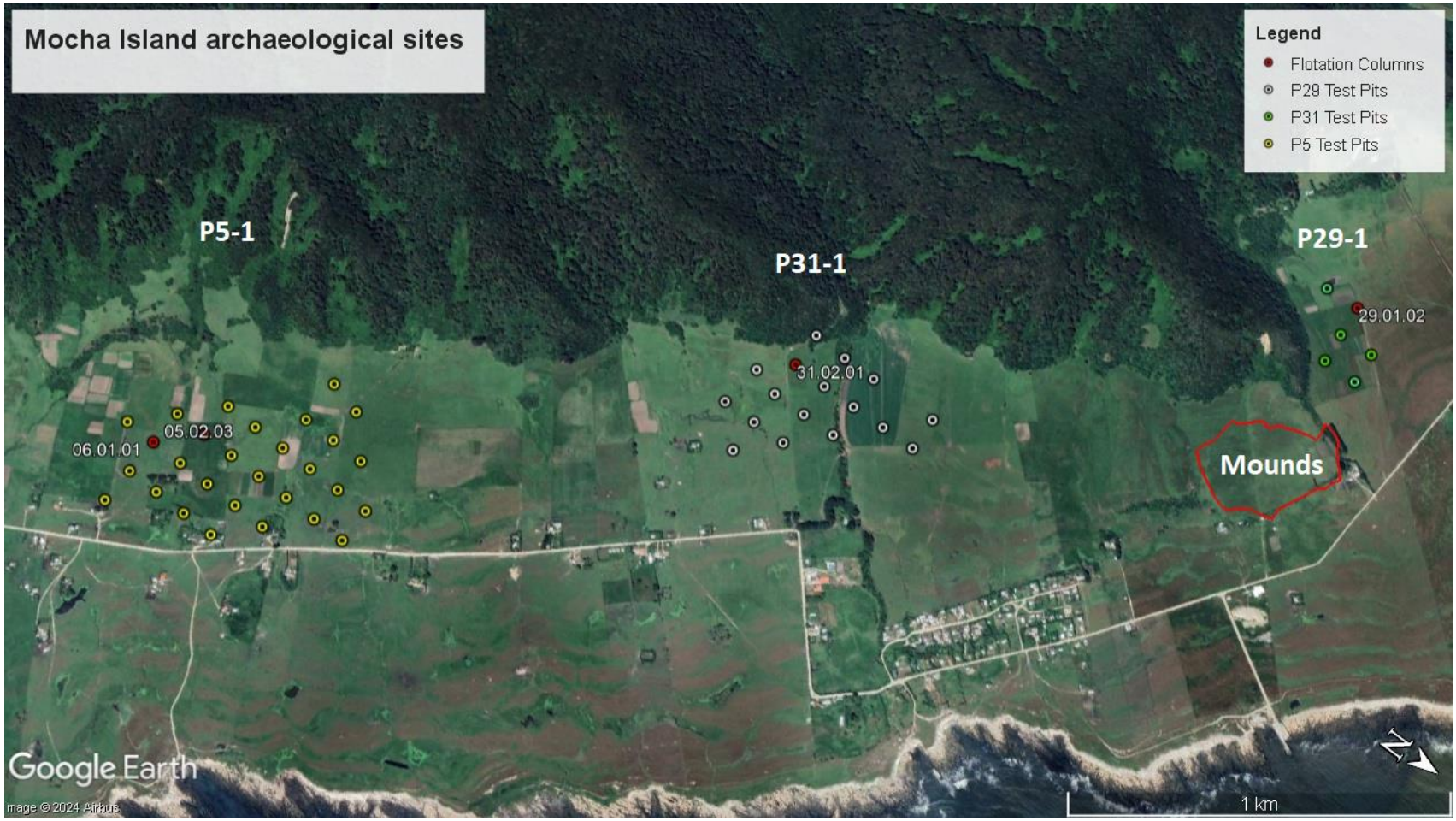


Figure 18: Test pits in the P5, P29 and P31 sites. Red dots indicate flotation columns.

7.2 The P5 site

The archaeological site is located on a Holocene marine terrace about 25 m ASL (Prieto 1997). Over the recent years, the surroundings of the site were destined as a pasture field for cattle. In terms of vegetation, only herbaceous plants were registered around the site during the last excavation season in 2013-2014 (figure 19), corresponding mostly to introduced weeds from the families Brassicaceae, Polygonaceae, Poaceae, Apiaceae, Asteraceae, Convolvulaceae and Fabaceae.



Figure 19: P5-1 (Photograph by the author, January 2015)

The site was first excavated in the 1994, but the materials considered for analysis were recovered during the summer fieldwork seasons of 2013 and 2014, as part of the research Project FONDECYT 3130515 leaded by Roberto Campbell Toro. The site has an extension of approximately 8 hectares, and it

was assessed using a systemic grid of test pits (hereafter, abbreviated as TP). The dimensions of each test pit were 100 x 50 cm, and they were placed 100 meters apart (figure 18). In total, 30 TP were excavated.

The site had eighteen previous ^{14}C dates (mostly AMS dates, only two conventional radiocarbon dates) and indicate a Late Ceramic occupation from the 950 to 1400 CE (detailed list of dates on table 5, appendix A). It is possible that the site was occupied until the abandonment of the Island, but no dates have been obtained to support this idea. During the 1990´s the site was considered to have an Early Ceramic component (Sánchez, Quiroz & Massone 2004), but there was only one pre-1000 CE date on unidentified charcoal that showed an error of over a hundred years. The later assessment of the site dismissed the ECP component because after calibration the date showed a wide temporal range of 651-1131 cal. CE (Campbell & Pfeiffer 2017), and no other ECP from the site dates were obtained. Only taxon dates have been obtained from the 2013-2014 excavation (Campbell 2020). But because of the taxon date prioritization, the basal levels of the test pits were not dated due to the few diagnostic or identifiable materials. The exception is TP 05.01.01, where two Archaic dates were obtained from *Pudu puda* bones recovered at the bottom of the test pit. Nevertheless, no cultural material was recovered from the archaic Layer, and no Archaic component was identified in any other part of the site.

During the 1994 excavation, human remains were found at a depth of 60-70 cm. The analysis indicated an almost complete female individual (20-25 years

old), who was buried in an extended position (diagnostic of the LCP) on a layer of seasnails shells of the species *Tegula atra* (Constantinescu 1997). Although more human remains were recovered in the 2013-2014 excavations (but without a discernible burial context), the site has been studied as a domestic context (Campbell 2020). The artefactual assemblage of the site shows similarity with the general LCP panorama of the Island: dense and reiterative use of the space, presence of a domestic ceramics assemblage (including large ceramic containers), and abundant food waste.

The analysis of the lithic materials from the site (n=1279) shows a toolkit orientated to diverse domestic activities such the manufacture of bone and wood artefacts, the obtaining and intensive processing of vegetal resources (gridding tools), and processing of other animal resources such as leather and/or bone (Peñaloza 2013). Obsidian and other foreign rock materials were also recovered at the site, along with other non-local materials such as metallic artefacts (Campbell *et al.* 2018).

The zooarchaeological assemblage indicates a diversified consumption of marine and terrestrial species (terrestrial and marine mammals, fish and birds, and invertebrates), but like the other LCP sites, there is a clear predilection for camelids (Roa *et al.* 2021). Bone instruments related to fibre and textile production were recovered in the site, along with other bone artifacts (Inostroza 2019). Old World taxa bones were also found in the site, such as *Bos taurus*, and *Ovis / Capra.*

The previous archaeobotanical analysis included macro and micro remains. Although these results will be integrated and discussed in a following section, the evidence indicate the consumption of crops such as maize, quinoa, and beans, but also wild species such as berries (*Aristotelia chilensis, Fragaria chiloensis, Luma apiculata* (DC.) Burret*, Rubus* cf. *geoides*) and other fruits *(Cryptocarya alba, Peumus boldus*). Considering the archaeobotanical and zooarchaeological data, it is clear that the vegetal and animal resources were processed and consumed in the site (Roa *et al.* 2021). This is also supported by the ceramic assemble of the site (3175 fragments), showing a high proportion of big to medium size jars and pots probably destined for the processing and storage of food (López 2017).

7.2.1 Material provenance and stratigraphy

The test pits with the highest density of materials were TP 05.02.03 and TP 06.01.01, located only 141.5 meters apart. Adjacent to each of these test pits, a stratigraphic column of 25x25 cm was extracted for flotation. The stratigraphic columns were taken after the TP reached an archaeologically sterile layer at 115 cm.

The sediment samples were bagged separately according to each layer and every 5 cm of depth, so the average volume of each sample was 3.125 litres. An additional sample of 3.8 litres was obtained from a concentration of wood charcoal in TP 05.02.03. The samples were floated using a flotation machine

and the resulting materials from the heavy and light fractions were sorted using a binocular microscope (7-45X). The charred seeds from the site were analysed in 2013, while the wood charcoal from 06.01.01 was analysed in 2016 as part of my undergraduate dissertation (Delgado 2017). The wood charcoal analysed as part of my PhD project includes the samples from the flotation column of test pit n° 05.02.03, as well as some charcoal samples handpicked during the excavation of the same test pit. Since the excavation of the test pits was also conducted using artificial layers of 5 cm, the excavation samples are easy to compare with the flotation samples. The previous wood charcoal results from the TP 06.01.01 will be compared and the integrated along with the other archaeobotanical information of the site.

In terms of stratigraphy (table 5), four layers were registered in the test pit 05.02.03 which are equivalent to the layers identified in 06.01.01 (although with different depths). Considering the stratigraphical layers and the chronology, it is relevant to mention that most of the previous dates for the site were concentrated in Layer II, and they show similar time ranges (1250-1400 CE).

In order to reinforce and extend the sequence, three dates were obtained from *Fuchsia magellanica* Lam. wood charcoal fragments, the only native woody species of the Onagraceae family found in the temperate forest of Southern Chile. This species was chosen because of is one of the taxa that is possible to identify with certainty to the species level, and because of its shrub habitus or life form it has a shorter life span than most trees (around 50 years). Two samples were obtained from Layer II (upper and bottom section of the layer) in

order to corroborate the sequence of the layer, and one sample was taken from layer IV to date the beginning of the LCP site occupation.

Table 5: P5-1 stratigraphy.

Layer	Description based on test pit 05.02.03
L I **0-30 cm**	Superficial layer showing disturbance by recent farming (ploughing). Sediment: rich organic brown matrix with few seashell inclusions. Relevant finds: over 700 pottery fragments were recovered. Dating: no ^{14}C dates.
L II **30-80 cm**	Fieldnotes indicates less disturbance in comparison to L I (less fragmentation of archaeological materials). Sediment: Similar texture and colour to L I, but a considerable raise of the shell inclusions differentiates L II from L I. Relevant finds: less pottery fragments were recovered (344), but they were bigger in size. A separated flotation sample of 3.8 l was taken from a concentration of ashes and charcoal identified between the 50-65, labelled as feature 1 (*Rasgo 1*, hereafter abbreviated as F1).
L III **80-100 cm**	Sediment: yellow colour with more clay than the previous layers. Abundant shell fragments were registered in this layer along with small charcoal inclusions. Relevant finds: 121 ceramic fragments.
L IV **100-115 cm**	Sediment: mostly yellow clay much compacted than the previous layers. No shell inclusions or fragments were registered. Relevant finds: two ceramic fragments and a small obsidian flake. Only wood charcoal was recovered in the deepest levels.

7.2.2 AMS dating results: P5 Chronology

All the previous eighteen ^{14}C dates of the site were calibrated incorporating the new three AMS dates (figure 20, details of the dates are provided in table 5, appendix A). The calibration was done in OxCal 4.4 using the SHCal20 calibration curve (Hogg *et al.* 2020).

The two Archaic dates (2135-1933 cal. BCE and 2022-1774 cal. BCE) were obtained from *Pudu puda* samples (terrestrial mammal non-native to the Island). The other Archaic dates obtained in the P27-1, and P30-1 sites correspond to unidentified charcoal and shell samples. These two deer dates are at the moment the earliest taxon date of non-native taxa in Mocha Island, giving direct evidence of animal transportation/translocation since the Late Archaic Period (Campbell & Martínez 2017).

Following previous authors (Roa 2016, Sánchez, Quiroz & Massone 2004), the results from the Ceramic Period will be grouped in phases of 200 years: 1000-1200 CE, 1201-1400 CE, and 1401 to 1600 CE.

Between the Archaic and the Ceramic Period dates, there is a hiatus of more than 2000 years in the P5 site. The current dates do not show a clear occupation of the site during the ECP. The pre-1000 CE dates (854-1019 cal. CE and 887-988 cal. CE, both wood charcoal samples) indicate the beginning of the Ceramic Period sequence (figure 21), and in stratigraphic terms this corresponds to Layer IV.

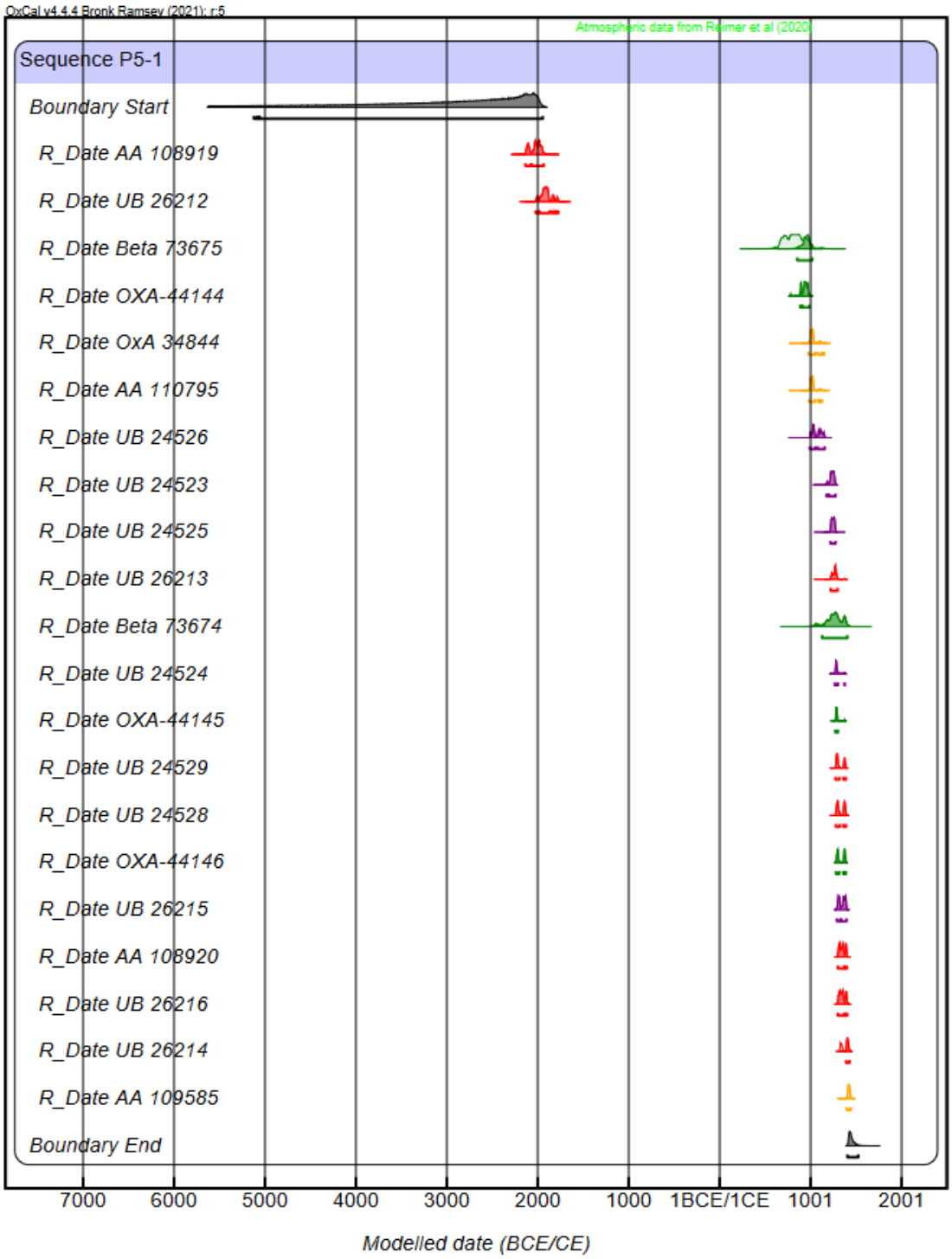


Figure 20: ^{14}C dates of the P5 site. Colours indicate sampled material: red= animal bones, green= wood charcoal, yellow= human bones, purple= crops.

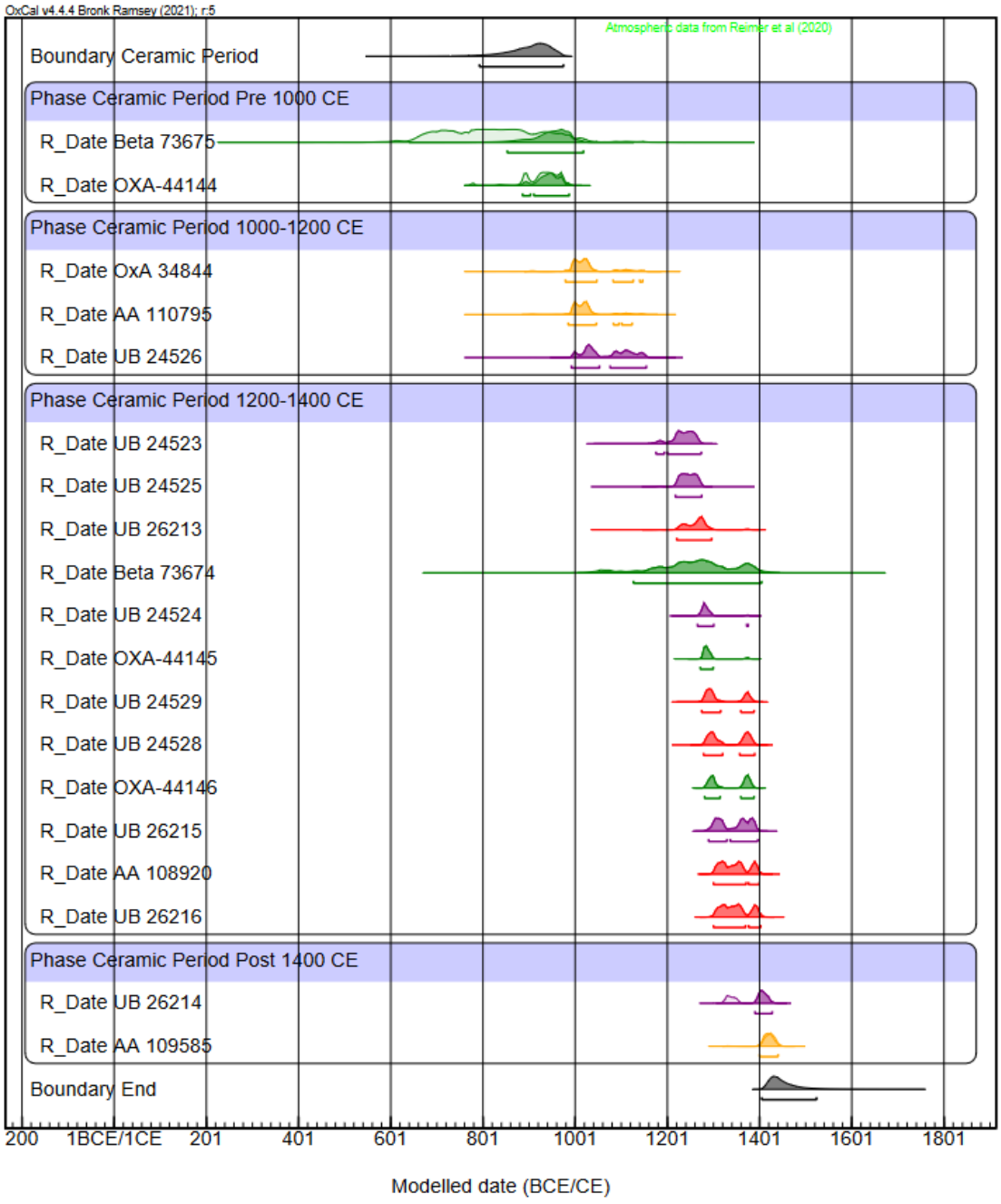


Figure 21: Detail of the ^{14}C dates for the Ceramic Period, P5 site. Colours indicate sampled material: red= Camelid bones, green= wood charcoal, yellow= human bones, purple= crops.

For the phase between the 1001 to 1200 CE, there are three dates but two of them do not have stratigraphical information (both correspond to human bone samples). The remaining date corresponds to maize (*Z. mays*) and was obtained from the base of Layer III in TP 06.01.01 t (85-90 cm). This date (993-1155 cal. CE) represents the earliest evidence of a cultivated plant in the P5 site. Since Layer III also provided an older date in TP 05.02.03 (1301-1401 cal. CE at 85-90 cm depth), it is not clear if this suggests stratigraphic disturbance or just different areas of the site. Taking in consideration the description of the layer provided by the field notebooks, Layer III seems to be a transition between Layer II and Layer IV (which suits the ^{14}C date discrepancy as well).

The phase between the 1201 and 1400 is the most dated, with twelve dates that includes samples of charcoal, crops, and camelid´s bones. In stratigraphic terms, most of the excavation sequence correspond to this phase. Depending on each TP, this phase usually represents more than 60 cm, which is substantial considering that 115 cm was the maximum depth reached in the site. The dates of the 1201-1400 phase are concentrated in Layer II, but there are also some dates from Layer I (layer with evident disturbance), and Layer III (as already mentioned).

There are only two dates for the Phase between 1401-1601, one from a maize sample (1391-1429 cal. CE) and another from human bone (1401-1441 cal. CE). The maize sample was recovered in Layer II (TP 05.02.03), but the human bone sample does not have stratigraphic information. Both dates do not go

much further after the 1400´s, and it is uncertain if the site was inhabited until the depopulation of the Island.

The three *F. magellanica* wood charcoal dates (Oxa-44144, Oxa-44145, and Oxa-44146) improved the chronological sequence of the site. In first place, the pre-1000 CE indicates human presence in the site before the main LCP occupation of the Island. Since this date was obtained from a Layer with scarce artefacts (L IV), it is also possible that the date represents a burning event (clearing of the forest). Although there is no direct evidence of an ECP inhabitation in the P5 site, people living in other sites during the ECP (such as the P-25 site) could have cleared different areas of the Island.

The other two dates (Oxa-44145 and Oxa-44146) were selected from the same depths where *Zea mays* taxon dates were obtained in order to compare them and evaluate possible disturbances in the sequence (figure 22). The previous dates of the TP showed a narrow temporal rage between the 1300 to 1400 cal. CE in over 50 cm of the sequence. A similar situation was observed in TP 06.01.01, where most of the dates showed a temporal range between 1200-1300 cal. CE. Although the wood charcoal samples produced slightly younger dates than ones from maize and camelid's bones, they confirm that most of the deposit from the site corresponds to the 1201-1400 CE phase.

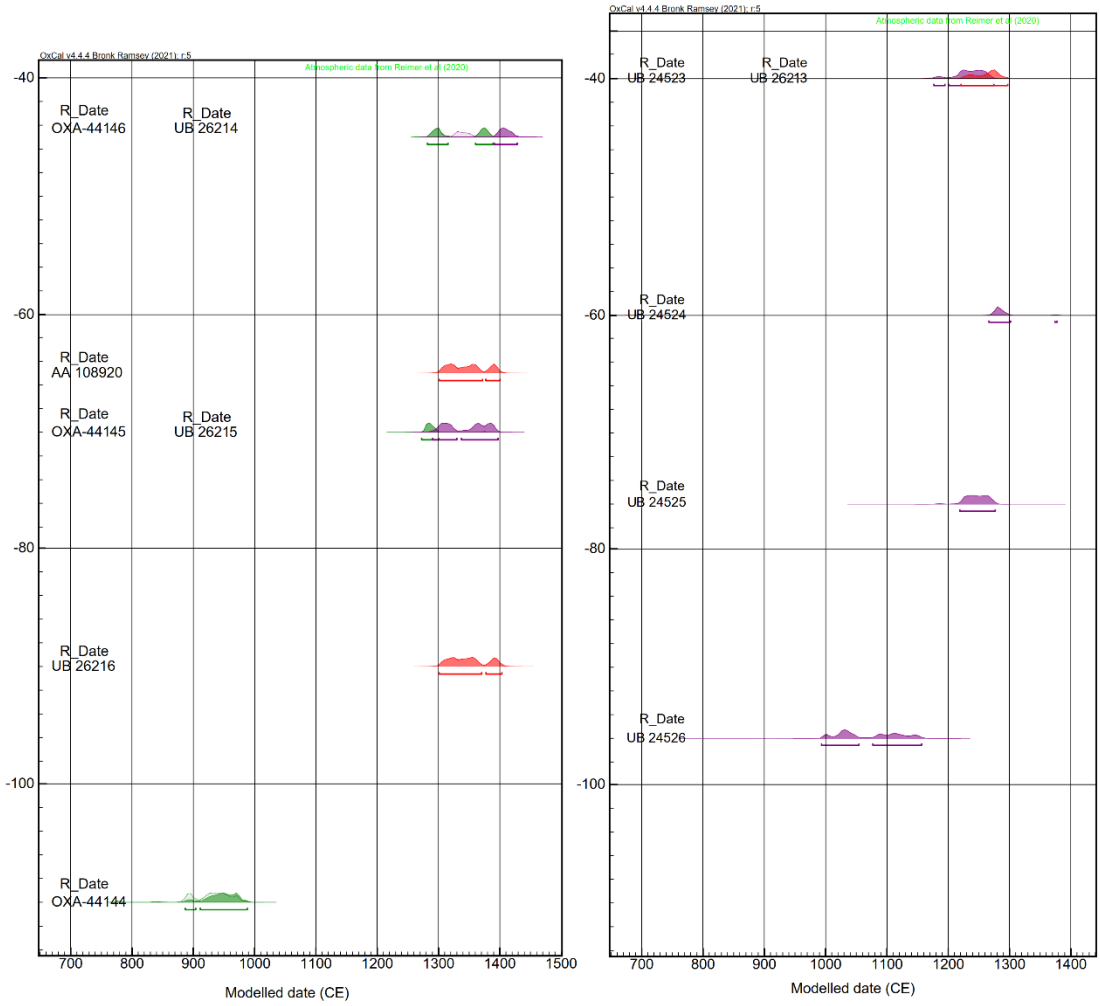


Figure 22: ^{14}C dates in relation to depth in (left TP 05.02.03 and right TP 06.01.01). Colours indicate sampled material: red= Camelid bones; green= wood charcoal; purple= crops.

7.2.3 Wood charcoal analysis results

A sum of 23 flotation samples (22 from the flotation column and one from a feature), and seven wood charcoal samples from the excavation were analysed. Because the sample from Feature 1 was not obtained systematically as the samples of the sediment column (difference in volume and covers more than 5 cm of depth), the information from Feature 1 will be presented separately when appropriate (hereafter abbreviated as F1).

Considering the weight of the samples, 83.5% of the charcoal was recovered through flotation (109.09 gr) and the remaining 16.5% was recovered during the excavation (21.6 gr). Most of the wood charcoal recovered through flotation material corresponds to fragments between 8-4 mm (35.6%), and 4-2 mm (32.3%). Overall, the distribution of the size categories does not suggest significant conditions affecting the fragmentation of the samples. Nevertheless, a higher percentage of bigger fragments (over 8 mm) was observed between the 60 and 70 cm (figure 23). The smallest fragments (under 2 mm) were recovered in slightly higher percentages between the 0-20 cm of depth, probably related to recent agricultural disturbance (ploughing and animal grazing). In the samples handpicked during the excavation, most of the fragments were over 8 mm (77%), showing a sampling bias towards bigger size charcoal fragments.

In terms of layers, most of the fragments were recovered in Layer II (83.9% of total), and among the flotation samples there is a peak between 55-70 cm of depth (53.4%). If the material from F1 is not considered, the peak is still visible

corresponding to the 44.6% of the weight from the flotation column samples. In the other end, Layer IV is the one with the less wood charcoal recovered.

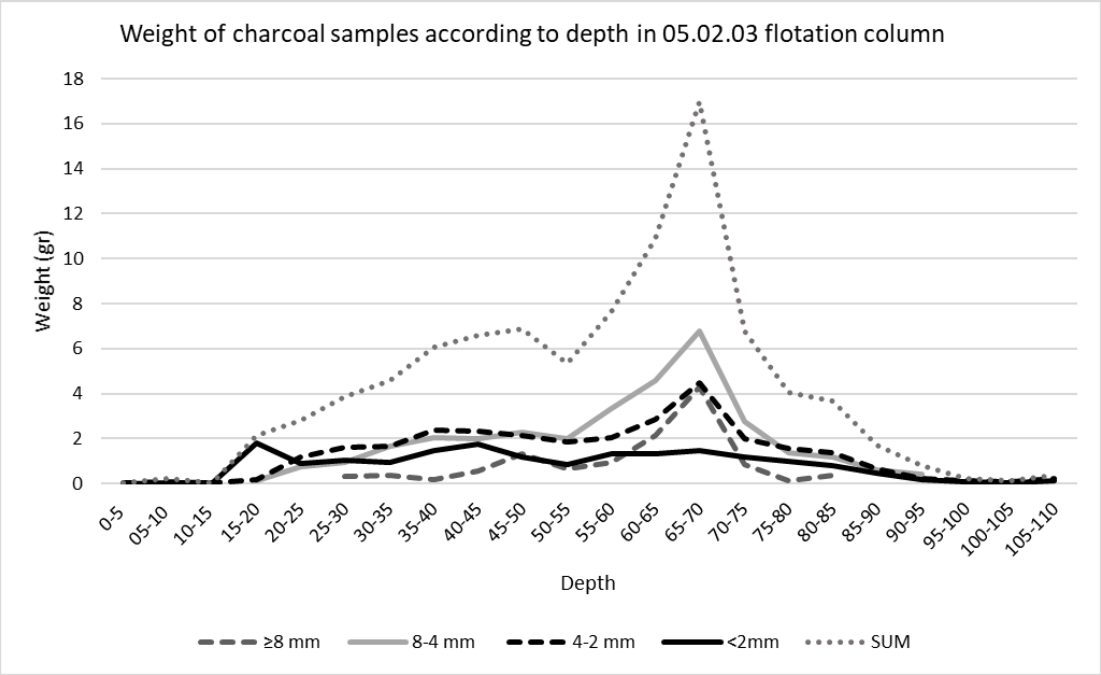


Figure 23: Weight of flotation samples from TP 05.02.03

A total of 982 carbonized fragments were analysed. Among them 951 wood charcoal fragments and six bark fragments were identified (figure 24). There were also other 25 fragments of an indeterminate vegetal tissue, but they were not considered in the final count. In total 615 wood charcoal fragments were identified (64.7 %), 132 were categorized as unknown angiosperm (21.5%), and 204 were classified as non-identifiable (13.9%).

In most of the flotation samples, the identified category represents more than 50% (figure 25). In terms of distribution, the samples with 50% or less of identified fragments are concentrated between the 0-15 cm and 85-100 cm of depth. The samples with the highest percentage of identified fragments (over

65%) were found between the 55 to 80 cm of depth. These tendencies are observable as well when grouping the samples by Layer. While Layer II (30-80 cm) shows 67.1% of identified and 17.9% of non-identifiable fragments, Layer III (80-100 cm) shows 46.2% of identified and 40.9% of non-identifiable fragments. Layer I (0-30 cm) and Layer IV (100-110) show similar percentages of identified (56.1% and 54.5% respectively) and non-identifiable fragments (31.7% and 35.6 % respectively). Although the taphonomical issues affecting the identification of the samples will be discussed in a following section, these percentages should be considered cautiously because of the differences in sample size. Layer II represents 77.2 % of the fragments from the flotation samples, while each one of the other layers represents less than 10%.

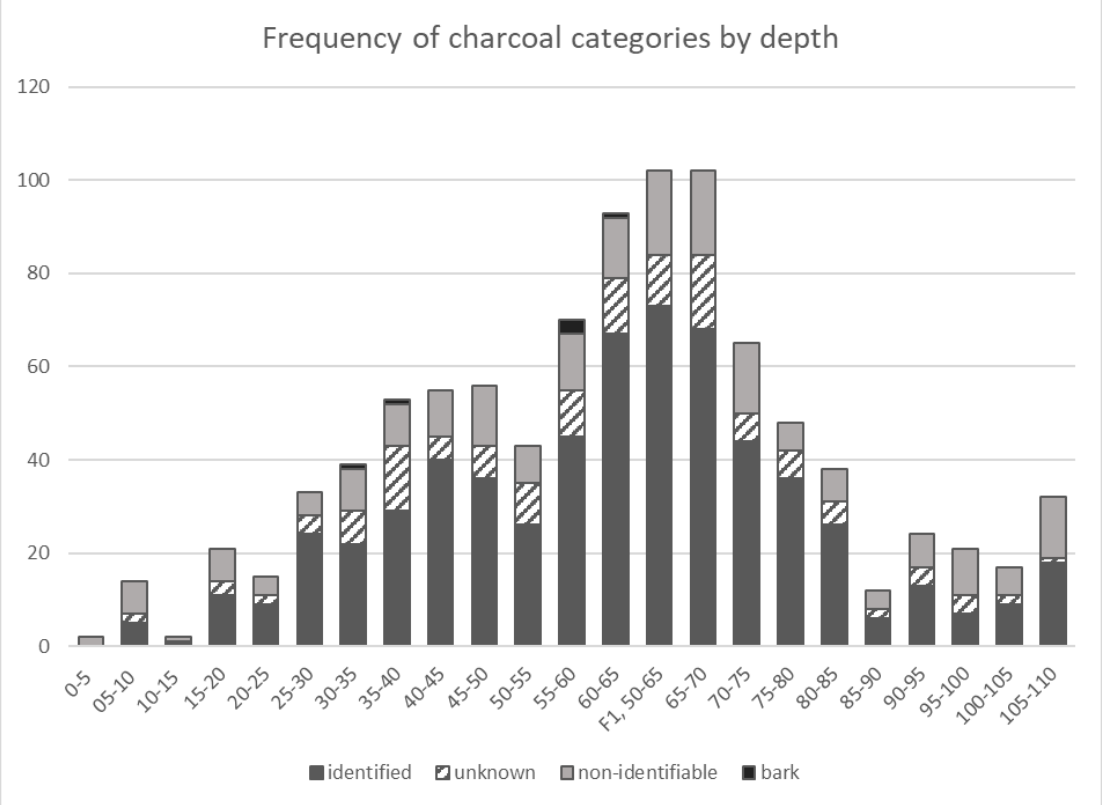


Figure 24: TP 05.02.03 charcoal categories.

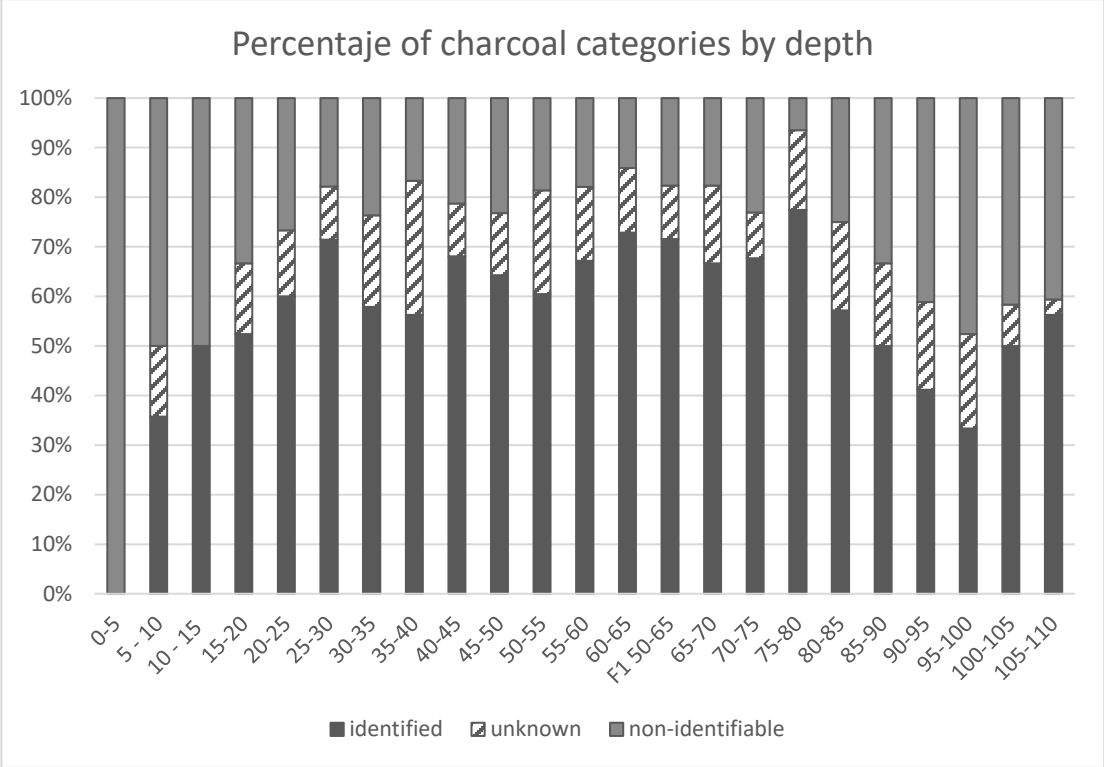


Figure 25: TP 05.02.03 percentages of charcoal categories from flotation column.

7.2.3.1 Identified taxa

A total of 24 angiosperm taxa were recognized, among them 23 correspond to dicots (Magnoliopsida) and only one to monocots (Liliopsida). Among the dicots, six of them were identified to species level, seven to genus level and ten to family level. As a whole, the identified taxa represent 17 families of native woody taxa (table 6, N= absolute frequency, %= percentage in relation to total of identified fragments, U= ubiquity).

The highest taxa richness is observed in Layer II (n=22, figure 26), the same layer that shows the highest diversity indexes (figure 27). The sample with the highest number of identified taxa (n=15), corresponds to the one taken between

65-70 cm (figure 26). This sample also presents the highest diversity Index (H=3.18).

Table 6: TP 05.03.02 identified taxa

Class	Family	Genus/species	N	%	U
Liliopsida (Monocots)			5	0.8	13.3
Magnoliopsida (Dicots)	Aextoxicaceae	*Aextoxicon punctatum*	40	6.5	63.3
	Anacardiaceae		1	0.1	3.3
		Schinus sp.	30	4.9	23.3
	Asteraceae		19	3.1	46.6
	Celastraceae	*Maytenus* sp.	2	0.3	6.6
	Cunoniaceae		37	6.0	33.3
	Elaeocarpaceae	*Aristotelia chilensis*	21	3.4	33.3
		Crinodendron sp.	1	0.1	3.3
	Ericaceae		1	0.1	3.3
	Fabaceae		8	1.3	16.6
	Grossulariaceae	*Ribes* sp.	9	1.4	13.3
	Lauraceae		2	0.3	6.6
		Cryptocarya alba	1	0.1	3.3
		Persea lingue	5	0.8	6.6
	Monimiaceae	*Laurelia/Laureliopsis*	81	13.2	66.6
		Peumus boldus	82	13.3	76.6
	Myrtaceae	Type A	208	33.8	76.6
		Type B	2	0.3	6.6
	Nothofagaceae	*Nothofagus* sp.	4	0.6	13.3
	Onagraceae	*Fuchsia magellanica*	42	6.8	43.3
	Proteaceae		4	0.6	3.3
	Rosaceae		3	0.5	3.3
	Scrophulariaceae	*Buddleja* sp.	7	1.1	20
Total			615	100	-

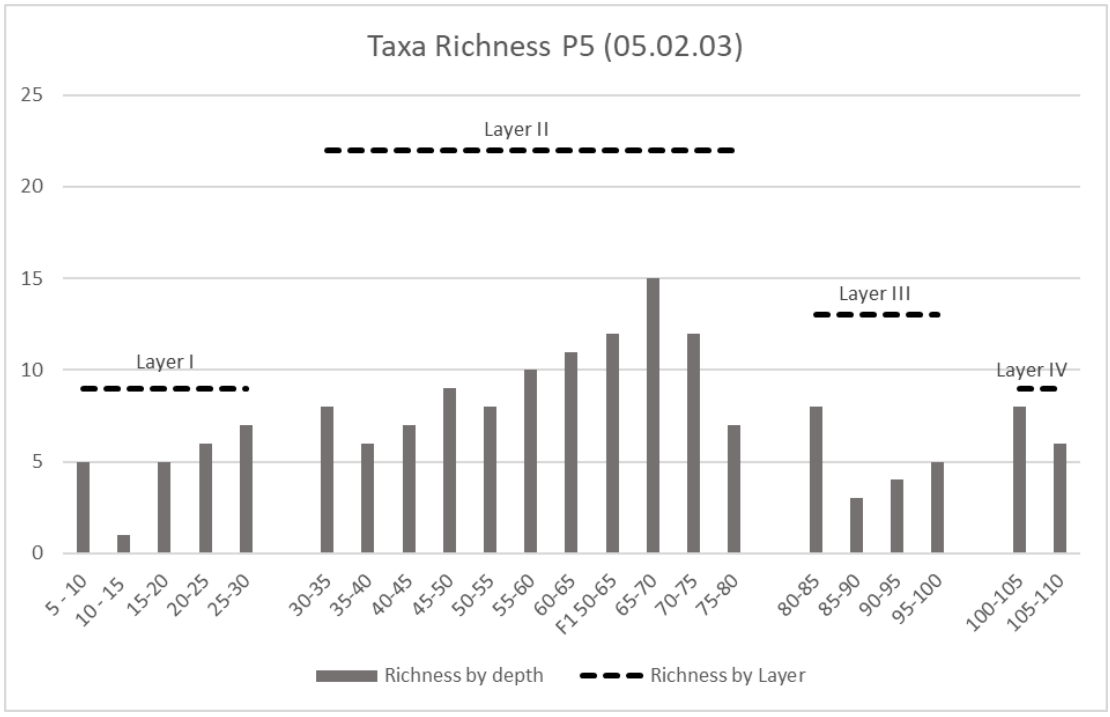


Figure 26: TP 05.02.03 taxa richness

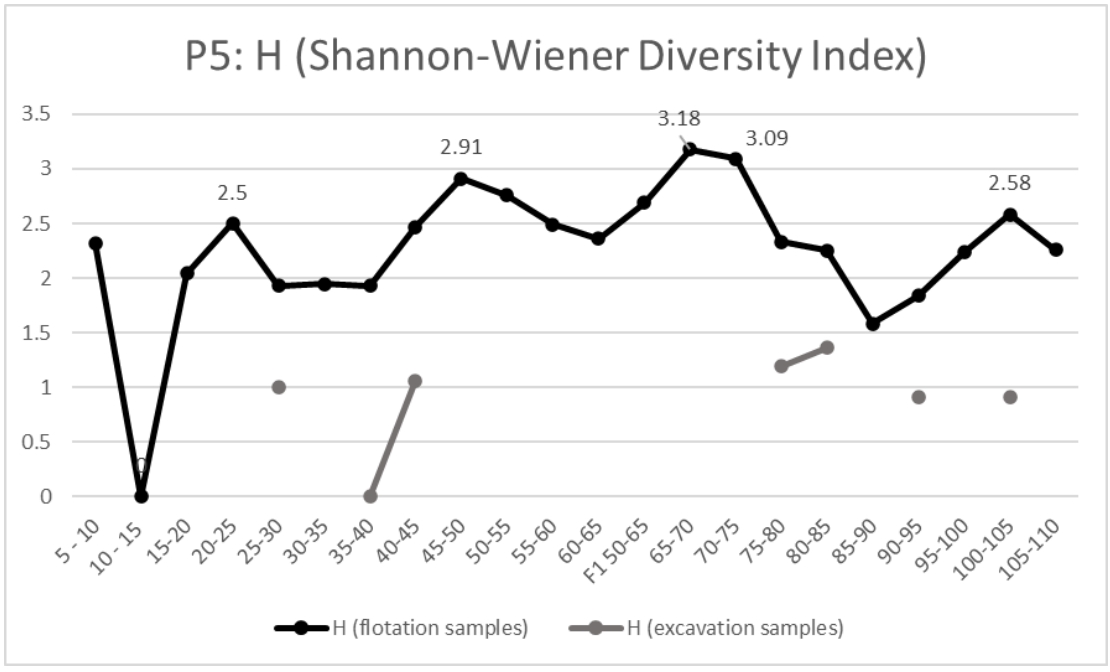


Figure 27: TP 05.02.03 sample's diversity index.

The most frequent identified taxon is Myrtaceae type A which groups the species of the family with diffuse porosity and small vessel size (complete description of all the identified taxa is provided in appendix B). A third of all the identified fragments correspond to Myrtaceae type A (33.8%), followed by *Peumus boldus* (13.3%) and *Laurelia/Laureliopsis* (13.2%), both tree species part the Monimiaceae family (table 6). These three taxa also show the highest ubiquity (figure 28). *Fuchsia magellanica* is the shrub with the highest frequency (6.8% of identified taxa). Other tree taxa with high frequency are *Aextoxicon punctatum* (6.5%) and the Cunoniaceae family (6%). *Aextoxicon punctatum* also shows a high ubiquity (63.3%).

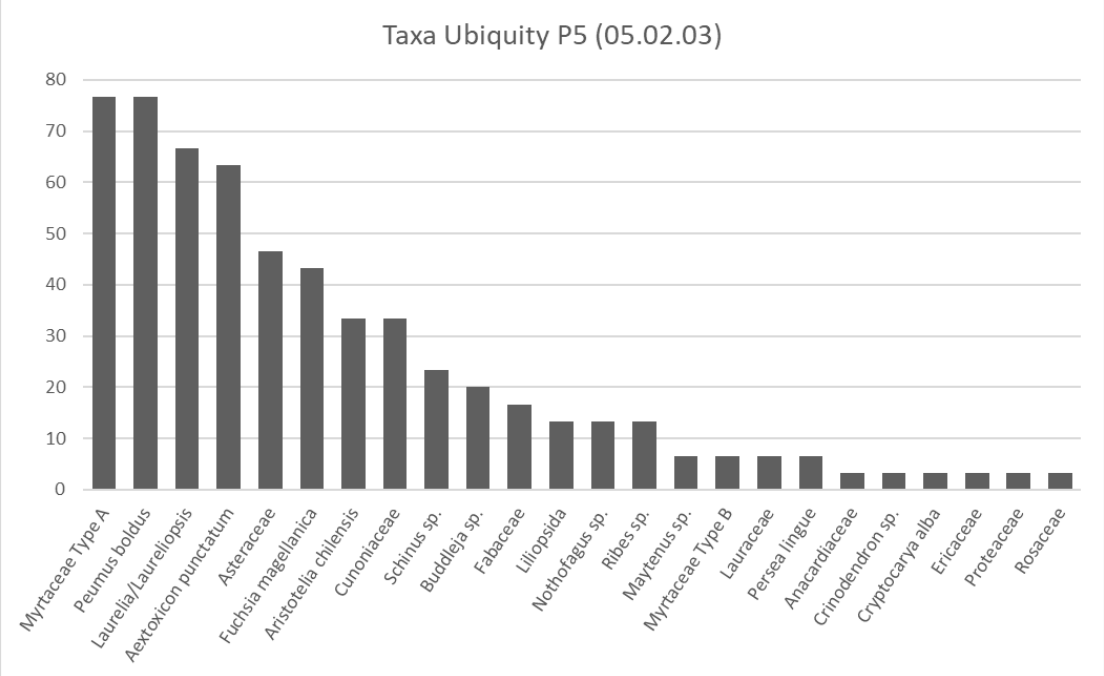


Figure 28: TP 05.02.03 taxa ubiquity.

In terms of relative frequency and only considering the flotation samples (figure 29), the Myrtaceae type A is the taxa that predominates in most of the samples between the 15 and 95 cm. Although *Peumus boldus* is the second ubiquitous taxa, its representation varies noticeable along the sequence, and as well as Myrtaceae type A, it was not identified in the deepest samples (Layer IV). Taxa such as *Fuchsia magellanica* and *Laurelia/Laureliopsis* seem to show a steady presence through the sequence. In the deepest samples (Layer III and IV), there is a noticeable percentage of taxa that was either not frequent or abundant in the upper ones, such as monocots and *Budleja* sp., nevertheless, because of the small sample size these percentages should be interpreted cautiously. This is also applicable to the case of *Aextoxicon punctatum*, a species that although is represented by few fragments shows a high percentage at the top and bottom of the sequence (just one fragment in the 10-15 samples representing 100% of identified category).

It was also observed that certain taxa such as *Persea lingue,* was only identified in Layer IV (n=5). In a similar way, the Proteaceae family was identified only in the sample from F1 (n=4).

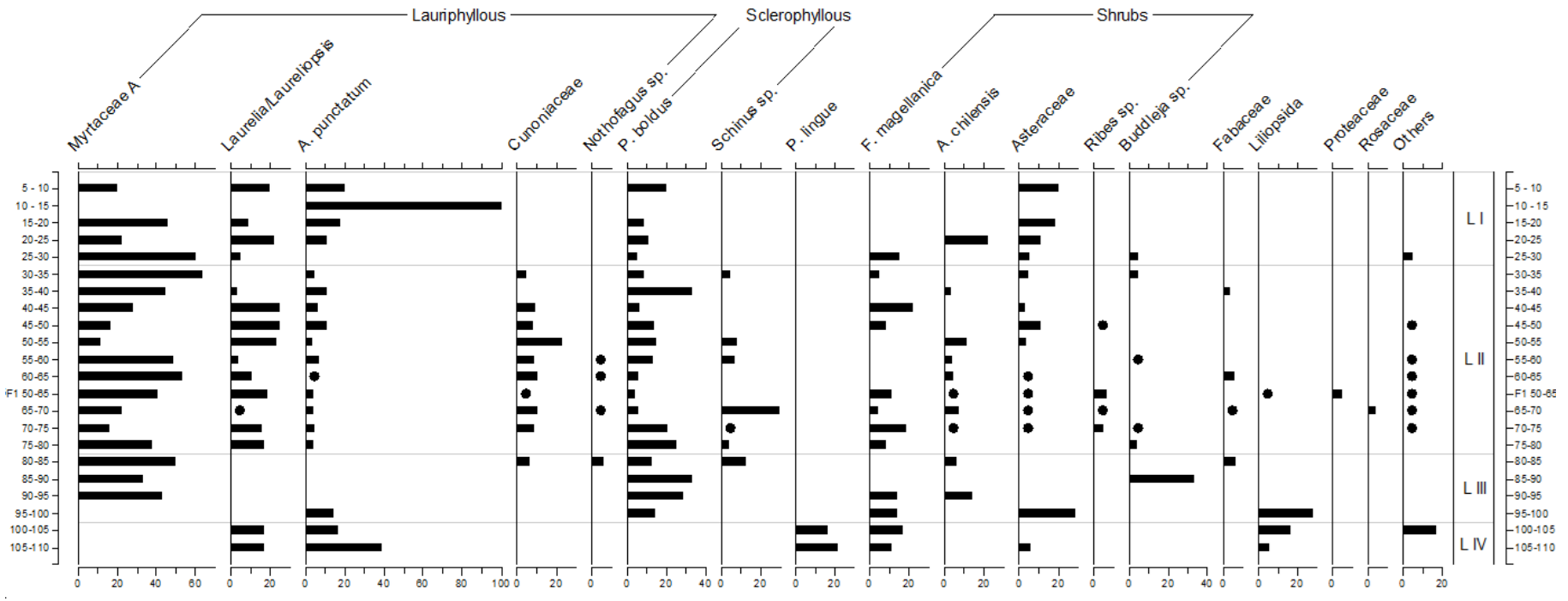


Figure 29: TP 05.02.03 wood charcoal relative frequency of flotation column. Circles represent values under 2%.

7.2.3.2 Unknown taxa

Among the unknown angiosperm fragments, there were two types observed in different samples (photos and description in appendix B). Type A was identified in all the samples between the 20 to 40 cm (table 7). Type B was registered only in three samples from Layer II, between the 50 and 75 cm.

Table 7: TP 05.02.03 frequency of unknown Type A and Type B

Unknown Fragments	Layer I		Layer II					Total
	20-25 cm	25-30 cm	30-35 cm	35-40 cm	50-55 cm	70-75 cm	F1	
Type A	1	1	3	3				8
Type B					1	1	1	3

7.2.3.3 Non-identifiable taxa

Among the 203 fragments categorized as non-identifiable, there is a high prevalence of alterations mainly related to taphonomical processes and anatomical issues (a more detailed discussion of taphonomy is presented in a following section). There are many fragments presenting more than one type of alteration, and in table 8 they are shown separately. But in this written section the values represent the sum of each alteration category as a percentage of the total of non-identifiable fragments (so percentages do not add up to 100%, since the same fragment might be considered under different categories). A 71.9% of the non-identifiable category presents at least one taphonomic feature, and part of this group show taphonomy and other alteration markers simultaneously (9.4% of non-identifiable fragments).

The second most frequent registered features were related to anatomical issues such as knots (15.7%) and small gauge fragments (4.4 %). The rest of the non-identifiable category was either too small to be identified (12.31%), or one of the plains could not be observed (mainly because of a needle-like shape of some fragments).

Table 8: TP 05.02.03 non-identifiable fragments

Non-identifiable fragments	**N**	**%**
Presence of one or more taphonomic features	127	62.56
Fragments too small to be identified	25	12,31
Alterations related to wood growth (compression/tension wood and knots)	18	8.86
Presence of one or more taphonomic features and alterations related to wood growth	14	6.89
Not possible to observe all anatomical sections	8	3.94
Small wood gauge (twigs)	6	2.95
Small wood gauge with presence of one or more taphonomic features markers	3	1.47
Not possible to observe all anatomical sections and presence of one or more taphonomic features	2	0.98
Total	203	100

7.2.3.4 Alterations in the wood anatomy of the assemblage

Along the sequence 45 fragments showed anatomical alterations registered as knots, and they were mainly identified in fragments over 4 mm (88.8%). Most of the fragments presenting knots were categorized as non-identifiable (71.1%), or unknown (15.6%). Only five identified taxa showed knots in small frequencies (table 9).

Table 9: TP 05.02.03 wood charcoal anatomical alterations

Category		**N**	**%**
Identified	Asteraceae	2	4.4
	Aristotelia chilensis	1	2.2
	Myrtaceae	1	2.2
	Peumus boldus	1	2.2
	Rosaceae	1	2.2
Unknown		7	15.5
Non-identifiable		32	71.1
Total		45	100

7.2.3.5 Diameter measurements of the assemblage

Because of the fragmentation of the wood charcoal samples, diameter could not be estimated. Nevertheless, ten fragments of Layer II showed a complete diameter, all corresponding to small gauge twigs (less than 2 cm of diameter). Only four of these ten fragments were identified taxonomically: *Fuchsia magellanica* (n=2), monocots (n=1) and *Laurelia/Laureliopsis (*n=1).

7.2.3.6 Taphonomy of the assemblage

A total of 343 fragments showed at least one taphonomic feature, representing a 36.1% of the analysed wood charcoal fragments. The most frequent features registered were vitrification and combustion cracks (n=308, 32.4%), both alterations related the combustion process (figures 30 and 31, V = vitrification, C= radial cracks). The presence of fungal and xylophage organisms was also observed (in figures 30 and 31 H= hypha), and in minor proportion other

features such as structural collapse and infillings were registered (groups as others= O in figure 30).

Among the identified fragments, a quarter showed at least one taphonomic feature (25%), while it reached nearly a third among the unknown category (32.6%). In terms of layers and depth, the highest percentage of fragments with taphonomic features was observed between the 65 to 75 cm (over 50%). In most of the other samples, the percentage of fragments with taphonomic features fluctuates between the 25 to 45 %, except in the more superficial samples with small number of fragments where it reached 100% (figure 31).

Because a significant part of the fragments showed more than one taphonomic feature simultaneously (n=50), the more frequent features are presented separately (vitrification and radial cracks), while the remaining ones were grouped in pairs. Although this means that the fragments with three different markers will be considered and counted in each of the three corresponding taphonomy categories, this facilitates the analysis of each category. This is relevant especially among less frequent markers, which otherwise might end grouped under a more frequent indicator.

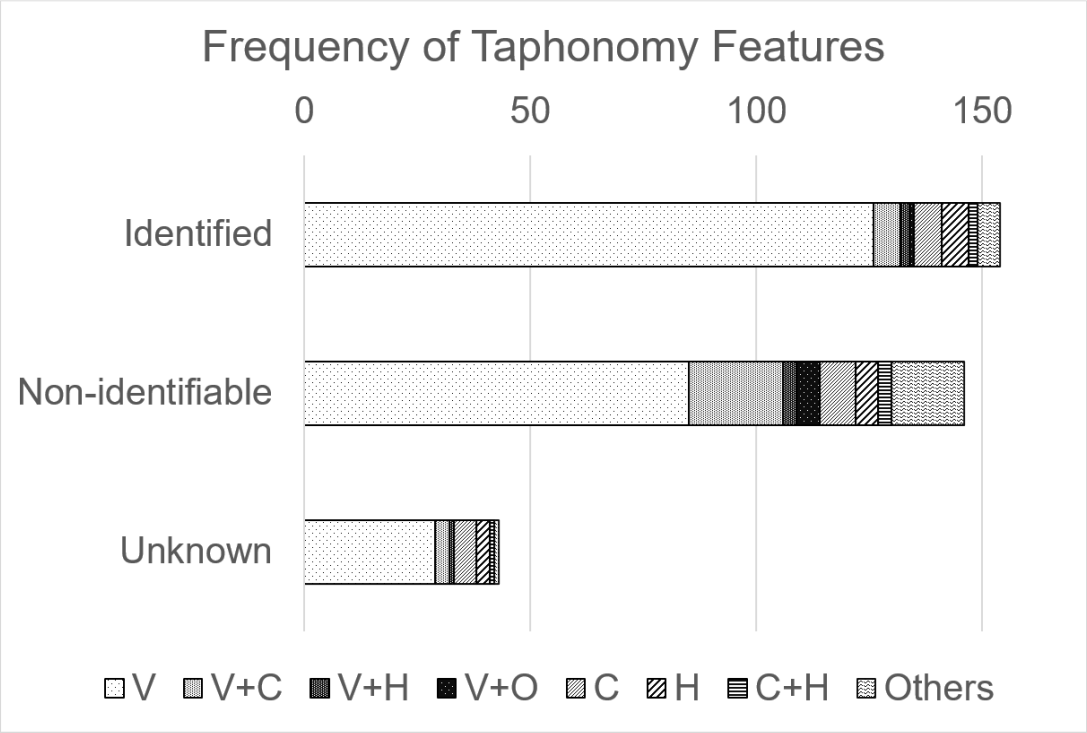


Figure 30: TP 05.02.03 frequency of taphonomic features (V: vitrification, C: radial cracks, H: hyphae, O: others).

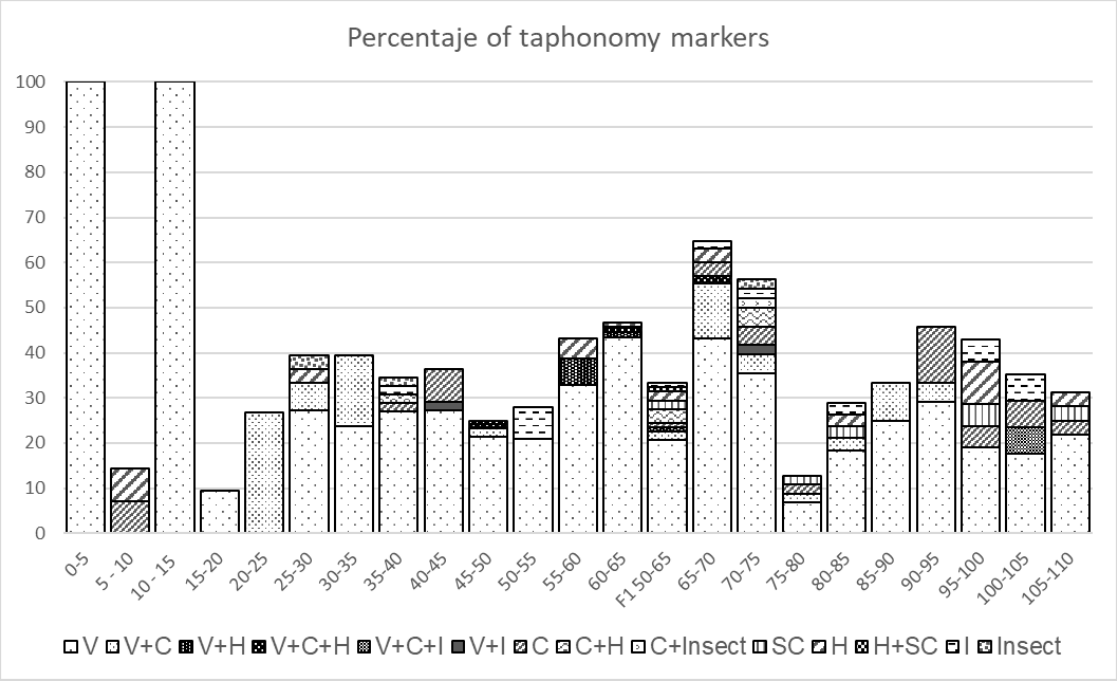


Figure 31: TP 05.02.03 percentage of taphonomic features. (V: vitrification, C: radial cracks, H: hyphae, I: infillings).

Vitrification was registered mainly on its own (n=240, 25.2%), and in less proportion along with radial cracks, hyphae, and infillings (figure 32, see details in table 6, appendix A). Among the identified fragments, the Myrtaceae type A presents the highest frequency of vitrification. The other taxa showing vitrification are the ones with high frequency in the site´s wood charcoal assemblage. This indicates that vitrification does not relate to taxa (and to specific anatomical features).

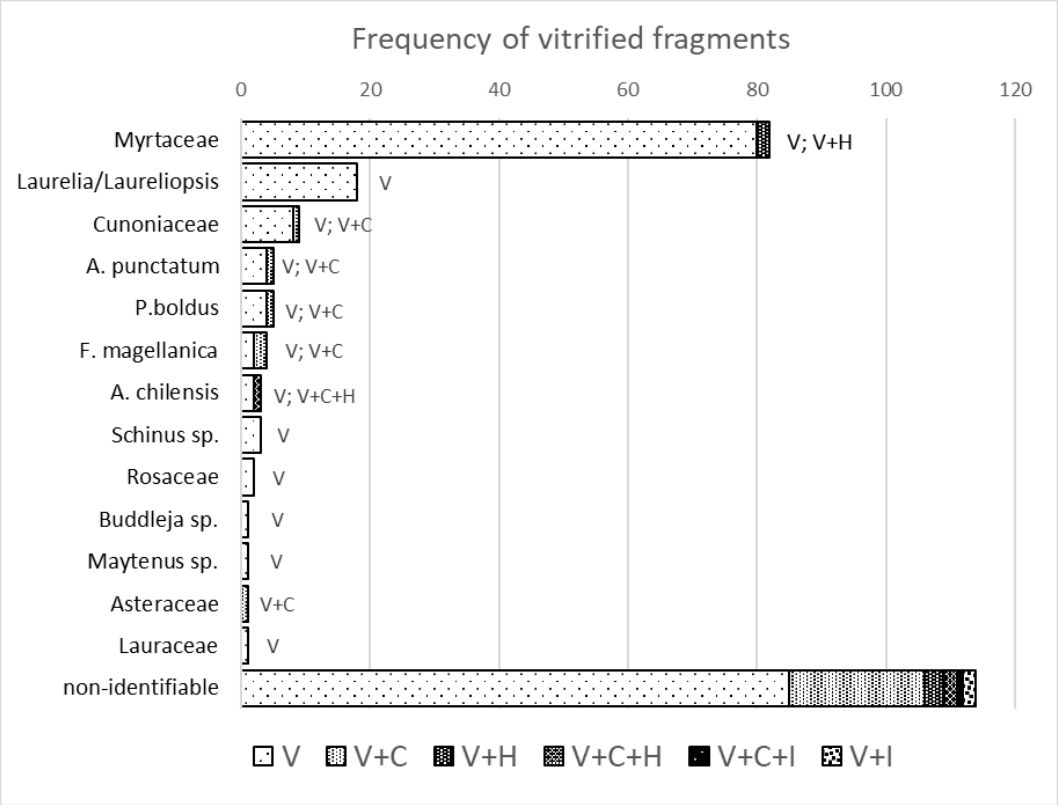


Figure 32: TP 05.02.03 detail of vitrified fragments (V: vitrification, C: radial cracks, H: hyphae, I: infillings).

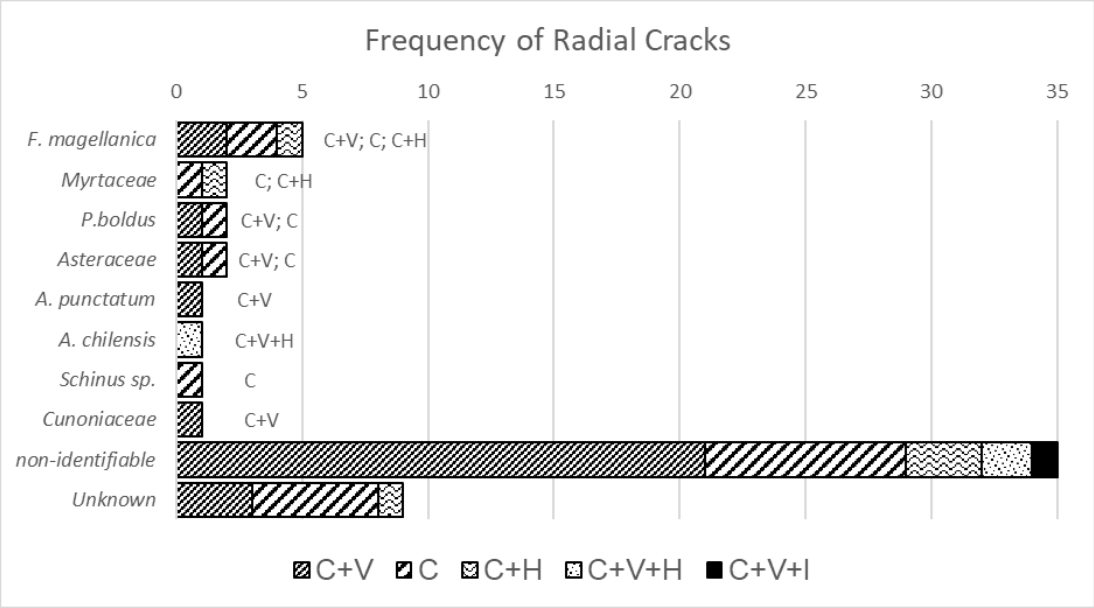


Figure 33: TP 05.02.03 fragments with radial cracks (C: radial cracks, V: vitrification, H: hyphae, I: infillings).

Most of the fragments showing radial cracks also showed vitrification (figure 33, see details in table 6, appendix A). There are few identified fragments showing radial cracks (n=15), nevertheless, most of them correspond to taxa with wide cell rays (more than three rows of cells), such as *F. magellanica*, *P. boldus*, Asteraceae, *A. punctatum* and *Aristotelis chilensis* (sum= 11).

Hyphae and indicators of xylophagous insects were identified as biological markers of wood decay in 68 fragments (7.2% of the site's wood charcoal total). Hyphae were identified mainly on its own but also along taphonomic features related to the combustion process (vitrification and radial cracks). Among the identified taxa, only seven taxa presented biological markers of wood decay (figure 34), while all seven showed hyphae, markers of xylophagous insects were registered in only two taxa: *F. magellanica* and *Laurelia/Laureliopsis*.

Infillings were registered in 13 fragments (mostly non-identifiable). Only two identified fragments presented infillings: one corresponding to the Myrtaceae type A and the other to *Ribe*s sp. Finally, structural collapse was recognized in eight fragments, all of them classified as non-identifiable.

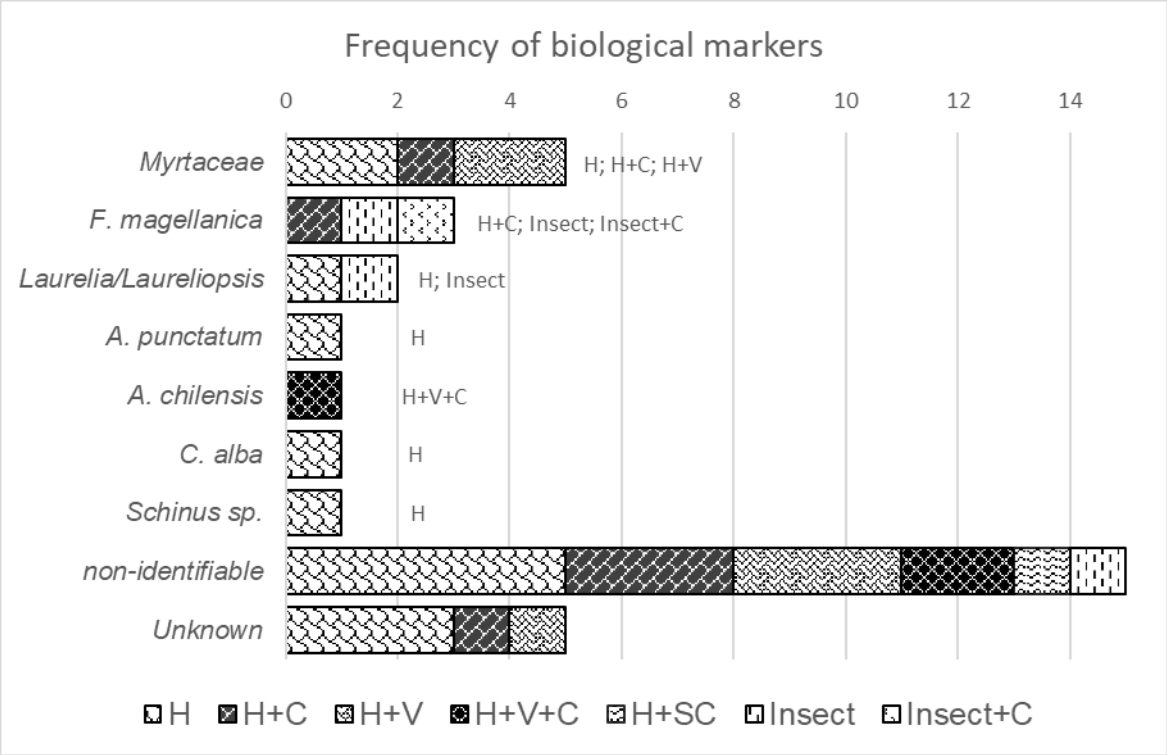


Figure 34: TP 05.02.03 fragments with biological markers (H: hyphae, V: vitrification, C: radial cracks).

7.2.4 Integration of the results with previous archaeobotanical information of the site

The previous archaeobotanical analysis of the sites includes wood charcoal, charred seeds and micro remains. The macro remains were mainly obtained through the flotation of the sediment columns from TP 05.03.02 and 06.01.01. The micro remains were also obtained from sediment samples of the same columns (Roa 2016), and in less amount from direct scraping of artefacts (Godoy-Aguirre 2018).

The wood charcoal analysis from TP 06.01.01 was conducted using almost the same methodology used for the analysis of TP 05.02.03. The major difference was that fragment size was not considered or registered in the 2016 analysis, and a random fragment selection was used instead. This could have influenced the number of identified fragments in TP 06.01.01 (50.2 %), which is lower than the one achieved in TP 05.02.03 (64.7%). The high percentage of non-identifiable fragments (41.5%) and the low one of unknown fragments (8.3%), could also reflect the random sampling used in the analysis.

A total of 23 woody taxa were registered in TP 06.01.01 (table 7, appendix A), being 17 of them also identified in TP 05.02.03. In a similar way as observed in TP 05.02.03, the most frequent taxa are Myrtaceae Type A, *F. magellanica*, *P. boldus, Cunoniaceae*, and *A. punctatum.* There are five taxa only registered in TP 06.01.01, most of them were identified in low frequency (less than 10 fragments per each taxon), except for *Escallonia* sp. (n=35). The three taxa registered in P5.02.03 but missing in TP 06.01.01 correspond also to taxa with

low frequency. In some cases, certain taxa were identified at different taxonomic levels in each of the TP. At genus level *Shinus* sp. was not identified in TP 06.01.01, but at the family level Anacardiaceae was identified, similarly A. *chilensis* and *Crinodendron* sp. were absent in TP 06.01.01, but at family level Elaeocarpaceae was identified. In the same way, at species level *C. alba* was identified in TP 05.02.03, and in TP 06.01.01 Lauraceae was identified at family level.

In relation to anatomical alterations, in the wood charcoal assemblage from TP06.01.01 an 11.9% of fragments show one or more taphonomic featurers (less than in TP05.02.03, where the equivalent percentage is 36.1%). Hyphae were the most frequently registered among them, representing two thirds of the fragments with taphonomic features (table 8, appendix A). When grouping hyphae and xylophage insects together as xylophage organisms, is noticeable that they are as twice as frequent in TP06.01.01 (8.4%) than in TP05.02.03 (3.6%).

Considering the woody taxa identified in both TP, 31 taxa were identified in the P5 site, representing 23 angiosperm families and monocots (table 7, appendix A). Among the identified taxa, 20 correspond to edible taxa (edible plant parts includes leaves, fruits, and associated edible fungi), and half the edible taxa also have other reported uses (mainly medicinal and dyes). Then, of the remaining eleven taxa, seven have medicinal or dyeing uses, but also three are known for good wood quality (details in table 23, appendix A).

The charred seed record of the site is composed predominantly by edible taxa (Roa 2016). Ten woody taxa were identified from the charred seed analysis (details in table 3, appendix A), representing nine different native angiosperm families (Roa *et al.* 2021). Five of the identified taxa are also represented in the wood charcoal record: *Aristotelia chilensis*, cf. *Cryptocarya alba*, *Peumus boldus*, cf. *Drimys winteri* and cf. Anacardiaceae. With exception of *D. winteri*, all these taxa have edible fruit. Two species of the Myrtaceae family were also identified: *Luma apiculata* and cf. *Ugni molinae*. Both species also have edible berries, and they could have been grouped in the wood charcoal record under the Myrtaceae type A taxon. The three remaining taxa were only identified in the charred seed record: cf. Cactaceae, cf. *Mitraria coccinea* and *Lapageria rosea*. These last two taxa are climbing shrubs with edible fruits. Cactaceae in the other hand, has never been described or mentioned in any of the Island ecological accounts but there are different cactus genera native to southern Chile (Rodriguez et al. 2018). Several cactus species have edible fruits, and the wood is quite good as fuel when it is dry.

The identification of micro remains from the sediment samples of the site had a low identification rate (Roa 2016). Phytoliths were the most identified among them, and very few starch grains were observed (including a *Zea mays* starch grain, Godoy-Aguirre 2018). The most frequent phytoliths correspond to Poaceae morphotypes that most likely represent an open surrounding of the site dominated by grass.

7.3 The P29-1 site

The site is located in a Holocene marine terrace, in an area used as an agriculture field. The site has an extension of 7 hectares approximately, and it was excavated in 2010 as part of the Project NSF BCS-0956229, as part of the PhD project of R. Campbell Toro (Campbell 2011). The site could not be assessed completely because the fieldwork season was interrupted by the 2010 earthquake and tsunami that affected the Chilean coast. Only six test pits of 50x50 were completed, also placed every 100 meters apart as in P5-1 (figure 18). A stratigraphic column of 35x35 cm was extracted adjacent to test pit 29.01.02 (figure 35).



Figure 35: TP 29.01.02, with a detail of the soil profile in the right side (photo courtesy of Constanza Roa, 2010).

The site has seven previous ^{14}C AMS dates that indicate a Late Ceramic occupation from the 1000 to 1400 CE (table 9, appendix A). As well as in P5,

it is possible that the site was occupied until the abandonment of the island. All the dates of the site were obtained from TP 29.01.02, among them there are only two taxon dates of Camelidae, and the four remaining ones correspond to unidentified wood charcoal.

In comparison to P5 site, there is less archaeological information available for P29 site, which reflects not only the different extension of the sites (P5 is one of the larger island sites), but also the fact that P29 was not excavated as initially planned (Campbell 2011). Even though the ceramic assemblage is composed of 1202 fragments (less than half of P5), and the lithics are only 244 (around a fifth of the ones from P5), proportionally, the site stands out in comparison to others for a high density of decorated ceramic fragments and foreign rocks by excavated cubic meter (Campbell 2020).

As part of the faunal assemblage, camelids, rodents, and small deer (*Pudu puda*) were identified among the terrestrial mammals, and bones of the Cetaceae and Otaridae families were identified among the marine mammals. The P29 site is the only site in the island where fish bones were the most frequently recovered animal remains, being even more frequent than mammals (Roa *et al.* 2021). No post-Hispanic animal taxa or human remains have been recovered in the site.

As well as in P5, the previous archaeobotanical analysis included carpology (charred seeds) and micro remains (Roa 2016). Macro remains of cultivated plants such as maize, quinoa and beans, were identified in the site along with other edible plants such as *Bromus sp.,* berries (*Aristotelia chilensis, Fragaria*

chiloensis, Rubus cf. *geoides, Ugni* sp.) and other fruits (*G. avellana*) The ubiquitous taxa are *Rubus* sp., *Chenopodium quinoa* and *Fragaria chiloensis.*

7.3.1 Materials and sampling

Adjacent to TP 29.01.02, a stratigraphic column of 35x35 cm was extracted for flotation (figure 35). Although the test pit reached a depth of 120 cm, the stratigraphic column only reached the 80 cm. The excavation had to be paused because of water saturation, and it could not be resumed because of the already mentioned 2010´s earthquake and tsunami. To overcome this sampling difficulty and study the entire site sequence, the analysed samples include the flotation column but also all the handpicked wood charcoal samples from the excavation, which were taken every 10 cm.

The sediment samples of the flotation column were obtained every 5 cm, so the average volume of each sample was 6.125 litres. The samples were floated using a flotation machine and the resulting materials from the heavy and light fractions were sorted using a binocular microscope (7-45X). The charred seeds record from the site was publish in 2014 (Roa, Silva & Campbell 2014), and the micro remains results were part of an unpublished Undergraduate dissertation (Roa 2016).

Although all the P29 dates come from the test pit where the flotation column was obtained, there are no available taxon dates from crops. In terms of stratigraphy, and similarly to P5, four layers were registered during the site

excavation (table 10). Four of the previous seven ^{14}C dates of the site are concentrated in Layer III. Since some of the dates obtained from Layer III are contemporaneous to the one from Layer I, the previous assessment of the site interpreted this as a possible effect of ploughing and/or vertical migration (Campbell 2011). In addition to these possible explanations, the old wood effect must also be considered since no taxonomic identification was done to the samples before dating.

Just as it was also done in P5, in order get a better understanding of the site´s chronology, three new dates were obtained. Two of the correspond to *Fuchsia magellanica* wood charcoal fragments, and one to *Drimys win*teri. This last species was chosen because as was the case of *F. magellanica, D. winteri* of is one of the taxa that is possible to identify with certainty to the species level because there is only one species of the genus and family in Southern Chile that can be found in geographical altitudes below the 800 m ASL (the other two species are constricted to the Andes and to the Juan Fernández archipelago, Rodríguez *et al.* 2018). In comparison with other native trees, this species has also a shorter documented life spam than other tree species (240 years according to Lusk & Del Pozo 2002). One sample from *F. magellanica* was obtained from Layer II (upper section), and another sample of the same taxa was selected from the middle of Layer III. The *D. wintery* sample was taken from the bottom of Layer IV in order to date the beginning of the site occupation.

Table 10: P29 site's stratigraphy.

Layer	Description based on test pit 29.01.02
L I **0-30 cm**	Superficial layer showing disturbance by recent farming (ploughing). Sediment: loose clay loam with fragmented shells. Relevant finds: glass fragments indicate recent disturbance.
L II **30-50 cm**	Fieldnotes indicates less disturbance in comparison to L I (less fragmentation of archaeological materials). Sediment: Similar texture and colour to L I, but a considerable raise of the shell inclusions and wood charcoal differentiates L II from L I. Relevant finds: Between the 40 and 50 cm, a hearth lens feature was described, but it was not excavated or labelled separately. From the field notes, it is not clear if the feature was in fact a hearth or a secondary concentration of wood charcoal and ashes, or if it was recognized in the entire test pit or just in a delimitated area.
L III **50-100 cm**	Sediment: loamy clay matrix with less charcoal and shells than LII, presenting a lighter colour than LII as well. This Layer concentrated four of the seven available dates of the site.
L IV **100-120 cm**	Sediment: sand and crushed shell fragments were registered, suggesting an ancient beach deposit. Except from wood charcoal, no archaeological materials were recovered between the 110 and 120 cm.

7.3.2 AMS dating results: P29 Chronology

The previous seven ^{14}C dates of the site were calibrated incorporating the new three AMS dates (figure 36, details of the dates are provided in table 9, appendix A). The calibration was done in OxCal 4.4 using the SHCal20 calibration curve (Hogg *et al*. 2020).

Unlike P5, all the dates from the P29 site correspond to the Late Ceramic Period and they are all concentrated between the 1000 and 1400 CE. To keep the dates comparable, they are grouped in phases of 200 years: 1000-1200 CE, and 1201-1400 CE (figure 37).

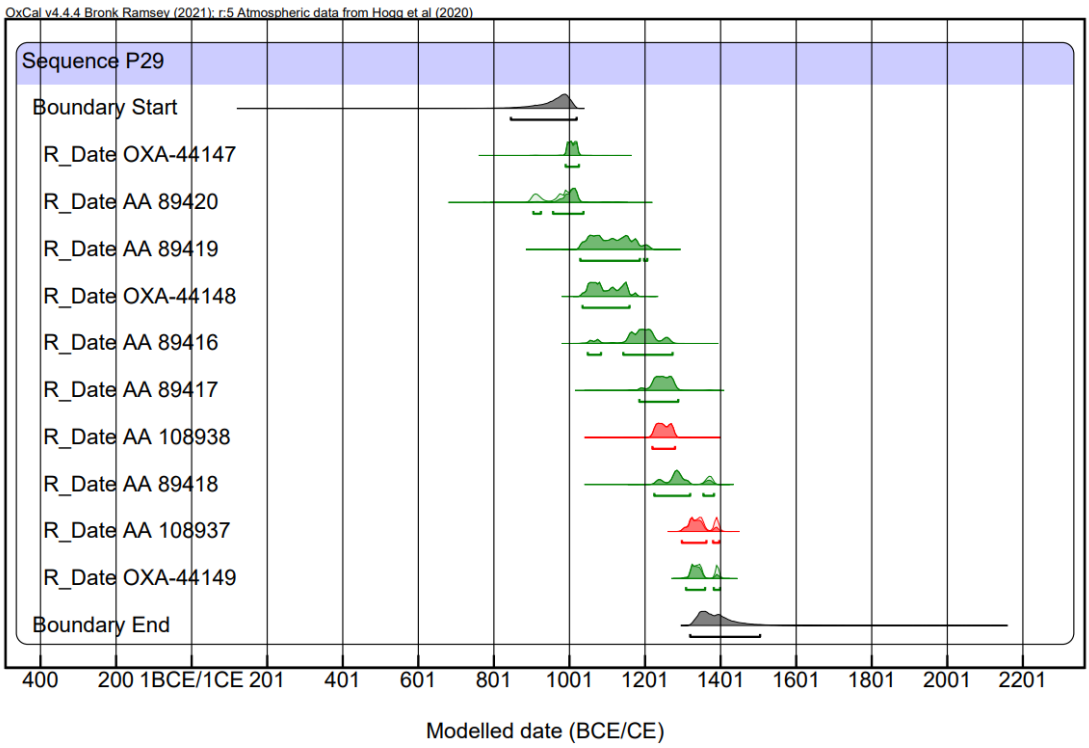


Figure 36: ^{14}C dates of P29 site. Colours indicate sampled material: red= animal bones, green= wood charcoal.

For the phase between the 1001 to 1200 CE there are four dates, all from wood charcoal samples obtained between the 70 and 120 cm of depth. The two deepest dates were obtained from Layer IV (110-120 cm), and only one of them was taxonomically identified as *D. winteri*. Both dates are very close to the year 1000 CE, and with the calibration they don't extend beyond the 1040 CE, indicating the beginning of the site's sequence. The other two dates were obtained from Layer III (70-100 cm), and only one was taxonomically identified as *F. magellanica*. Unlike the deeper ones, these two dates were recovered in sediments rich in archaeological material, suggesting a clear inhabitation of the site from 1100 CE.

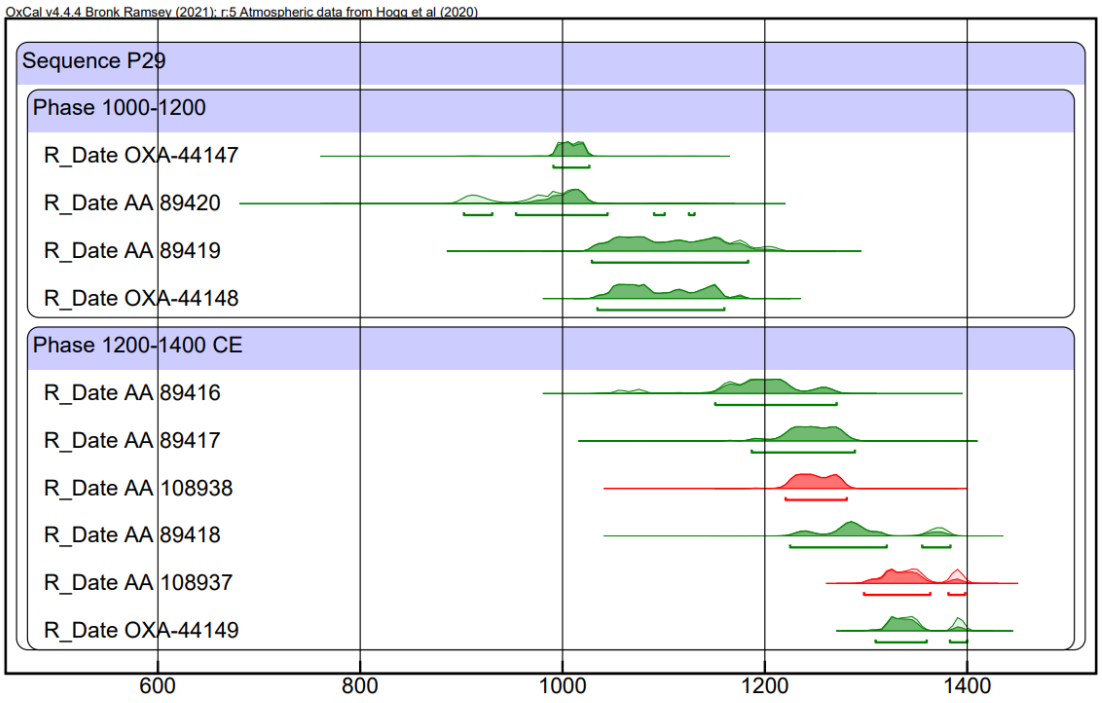


Figure 37: Detail of the ^{14}C dates for the Ceramic Period, P29 site. Colours indicate sampled material: red= animal bones; green= wood charcoal; yellow= human bones; purple= crops.

The phase between the 1201 and 1400 is the most dated with six ^{14}C dates that include two samples taken from bones of camelids. The dates were obtained from Layer I, II and III, between the 20 and 80 cm. In stratigraphic terms, some dates indicate either stratigraphic disturbance or sampling issues (figure 38). The three different dates obtained between the 70 and 80 cm (Layer III) indicate a temporal range from 1000 to 1400 CE. Then, the four top samples obtained between the 20 and 60 cm (Layer I, II and III) indicate a temporal range from 1200 to 1400 CE. In a similar way to P5, Layer III presents a wide temporal range (1000 to 14000 CE). Since the dates and the stratigraphy indicates a continuous inhabitation of the site, it is also possible that the top section of Layer III (50-80 cm) corresponds to a transition between Layer II and III. This could be product of spatial changes within the site (like the building of a new house) that involved the preparation/excavation of the sediment. Although with less dates, Layer II and Layer I represent the Phase between the 1200-1400 CE. Presently, It is still unclear if the site was inhabited at the moment of the European contact or until the Island's depopulation.

The three taxonomically identified wood charcoal samples improved the chronological sequence of the site and raised new questions. The early *D. winteri* date (OXA-44147, 991-1026 cal. CE) provides a robust beginning of the site's sequence. In a similar way to P5, the sample was obtained from the deepest Layer where not that many artefacts were recovered. For this reason, I suggest that in both sites these early dates from the Ceramic Period could represent trees older than the actual inhabitation, resulting from initial forest clearing.

The other two dates from *F. magellanica* (OXA-44148 and OXA-44149) were selected in order to corroborate the chronology of Layer II and III. For Layer III, the new dates expanded the chronological frame, and in Layer II it was possible to define with more certainty a chronological phase. Nevertheless, the contrast between taxonomically identified and non-identified samples opens the debate in relation to the old wood effect. As it is detailed in the following section, conifers were identified in the charcoal assemblage of the site. Some native conifers of the temperate South American forest can live more than 1000 years, but also some angiosperms are longevous (Lusk & Del Pozo 2002, Lusk 1996). It is not possible to rule out that some of the previous dates correspond to wood charcoal samples of long-lived taxa.

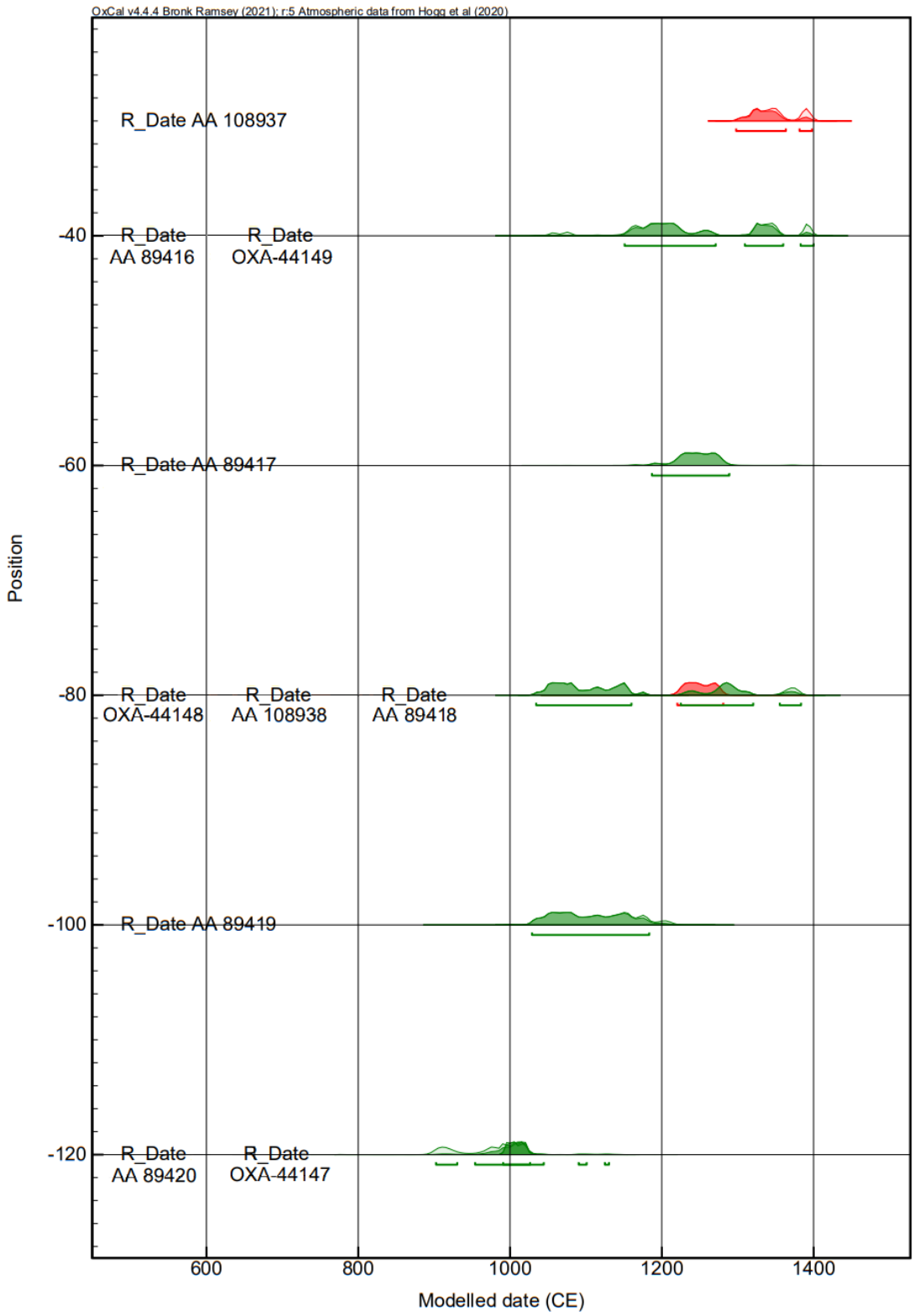


Figure 38: ^{14}C dates in relation to depth in TP 29.01.02. Colours indicate sampled material: red= Camelidae bones, green= wood charcoal.

7.3.3 Wood charcoal analysis results

A sum of fifteen flotation samples and eleven wood charcoal samples from the excavation were analysed. Considering the weight of the samples, 62.1% of the total wood charcoal assemblage was recovered through flotation (196.7 gr), and the remaining 37.9% percentage correspond to the handpicked samples recovered during the excavation (119.6 gr).

Most of the wood charcoal recovered through flotation material corresponds to fragments between 8-4 mm (32%), and 4-2 mm (32.3%). The distribution of each of the size categories follows the general trend of total weight of the samples and does not suggest deferential processes affecting the fragmentation of the assemblage. The only noticeable difference was observed among the bigger fragments (over 8 mm) which show a slightly higher percentage between the 45 and 50 cm (figure 39). In the excavation samples there was a clear bias favouring the recovery of big fragments (over 8mm), reaching 80.3%. In both flotation and excavation samples there is a peak of charcoal between the 40-50 cm (figures 39 and 40).

In terms of layers, most of the fragments were obtained from Layer II (48%) and Layer III (35.7%). Layer IV is the one with less recovered fragments: there is just one excavation sample that represents 0.09% of the total wood charcoal assemblage.

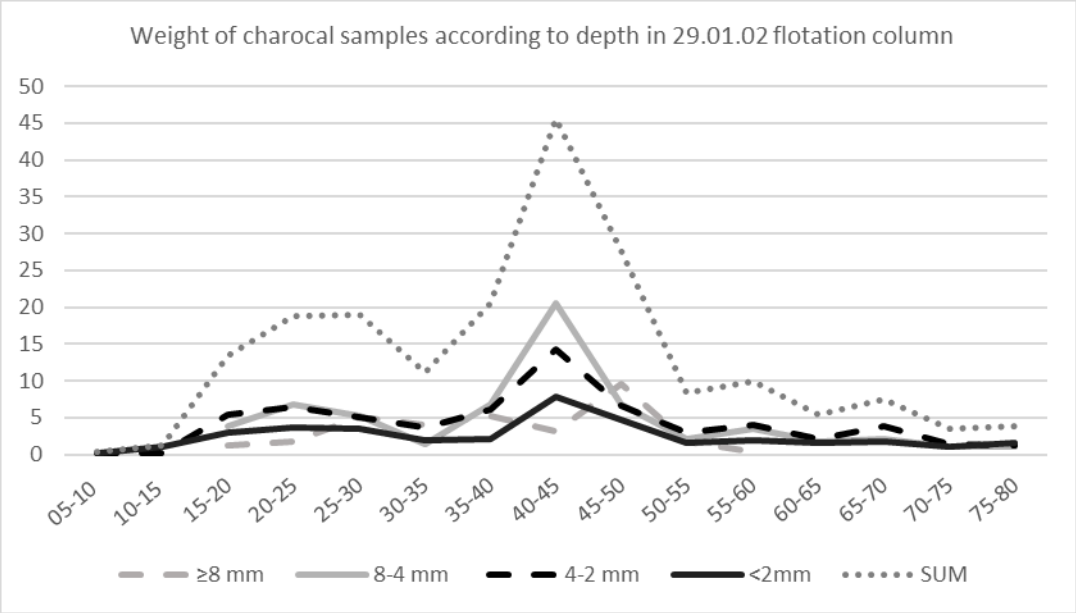


Figure 39: Weight of flotation samples from TP 29.01.02

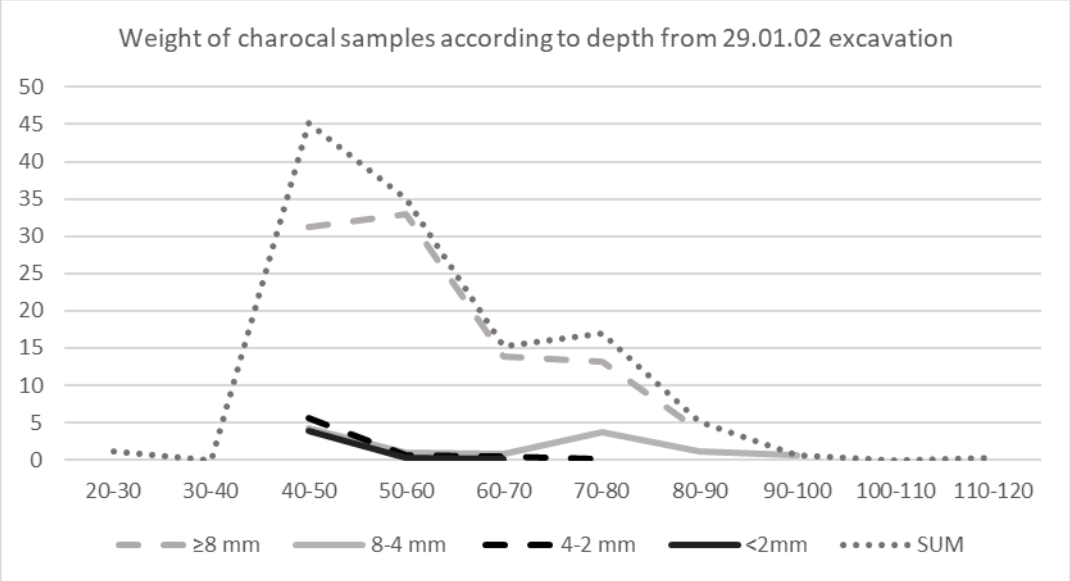


Figure 40: Weight of excavation samples from TP 29.01.02

A grand total of 1550 carbonized fragments were analysed, but among them, there were 27 fragments of and indeterminate vegetal tissue that is not

considered in the final count (figure 41). From the total of 1523 wood charcoal fragments, 1,084 were identified (71.2%), 124 were categorized as unknown angiosperm (8.1%) and 315 were categorized as non-identifiable (20.7%).

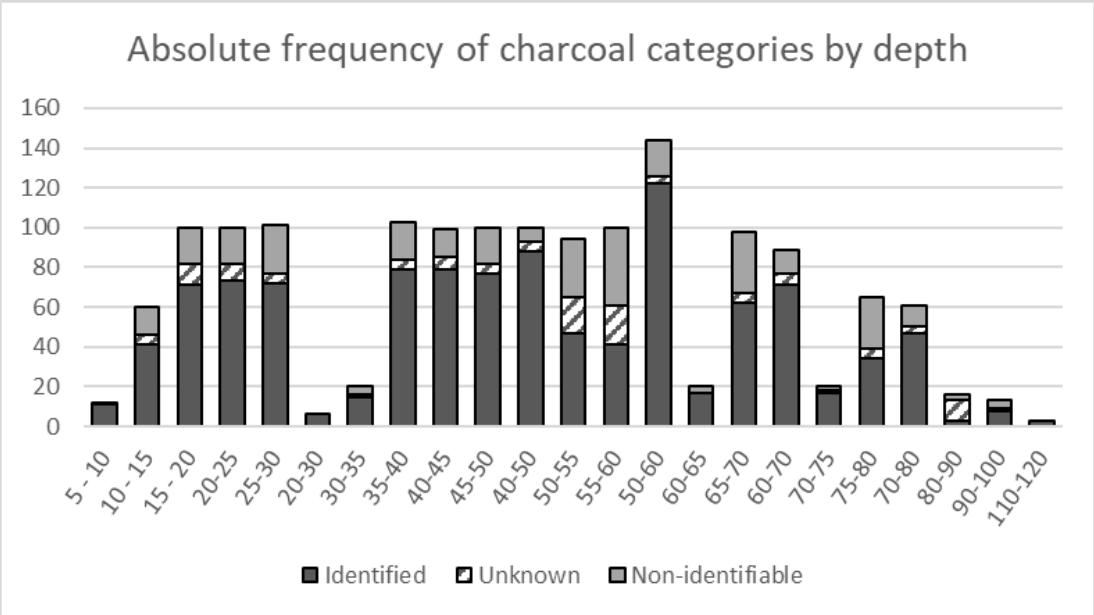


Figure 41: TP 29.010.1 charcoal categories.

In most of the flotation samples, the identified fragments represent more than 50% (figure 42). The flotation samples with lower identification rate are the ones between the 50 and 60 cm, and the one between the 75 and 80 cm. The excavation samples also show a high rate of identification, the exception is the sample from the 80 - 90 cm depth, showing a predominance of the unknown category.

If we compare the distribution of the identification categories by layer, we observe that in all of them the identified fragments represent more than 65%. Without considering Layer IV (small samples size), Layer II shows the highest identification rate (80.1%). The highest percentage of non -identifiable fragments was found in Layer III (26.6%), which was already noticed in the previous paragraph when comparing the samples by depth. The unknown category shows similar percentages in all the layers (between 5% - 10%).

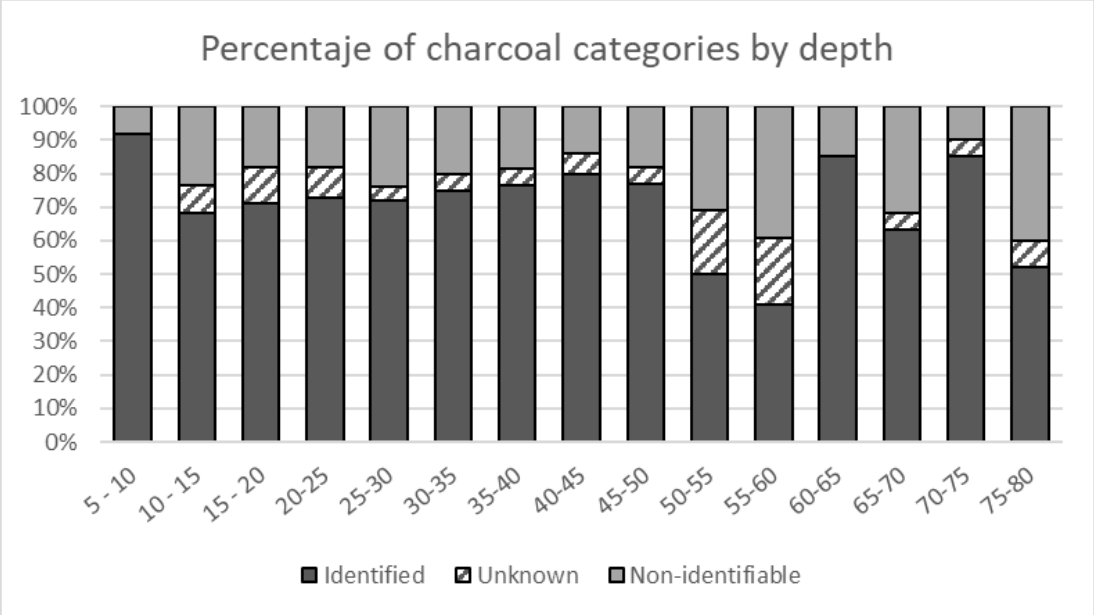


Figure 42: TP 29.01.02 percentages of charcoal categories from flotation column.

7.3.3.1 Identified taxa

A total of 20 taxa were recognized, including one conifer taxa (identified to class level as Pinopsida) and 19 angiosperm taxa. Among the angiosperms, only one taxon was identified to class level as monocots (Liliopsida). Of the remaining

18 dicots taxa, four were identified to family level, two to subfamily level, six to genus level, and six to species level. As a whole, the identified taxa of the site represent 16 families of native woody taxa (table 11, N= absolute frequency, %= percentage in relation to total number of identified fragments, U= ubiquity).

Table 11: TP 29.01.02 identified taxa

Class	**Family**	**Genus/species**	**N**	**%**	**U**
Pinopsida (Conifers)			10	0.9	23.1
Liliopsida (Monocots)			3	0.3	7.7
Magnoliopsida (Dicots)	Aextoxicaceae	*Aextoxicon punctatum*	17	1.6	26.9
	Asteraceae		21	1.9	46.1
	Celastraceae	*Maytenus* sp.	5	0.5	3.8
	Cunoniaceae		14	1.3	23.1
	Elaeocarpaceae	*Aristotelia chilensis*	14	1.3	30.8
	Ericaceae		83	7.6	38.5
	Grossulariaceae	*Ribes* sp.	38	3.5	46.1
	Monimiaceae	*Laurelia/Laureliopsis*	8	0.7	23.1
		Peumus boldus	15	1.4	30.8
	Myrtaceae	Type A	663	61.2	95.1
		Type B	8	0.7	23.1
	Nothofagaceae	*Nothofagus* sp.	6	0.5	15.4
	Onagraceae	*Fuchsia magellanica*	109	10.1	73.1
	Quillajaceae	*Quillaja saponaria*	1	0.1	3.8
	Salicaceae	*Azara* sp.	1	0.1	3.8
	Scrophulariaceae	*Buddleja* sp.	1	0.1	3.8
	Verbenaceae		1	0.1	3.8
	Winteraceae	*Drimys winteri*	66	6.1	38.5
Total			1084	100	-

The highest taxa richness is observed in Layer I (n= 19), and the sample with the highest number of identified taxa correspond to the one taken between the 25-30 cm (n=13, figure 43). Although Layer II shows high diversity indexes (figure 44), the sample with the highest value is the one taken between the 75-80 cm (H=2.64).

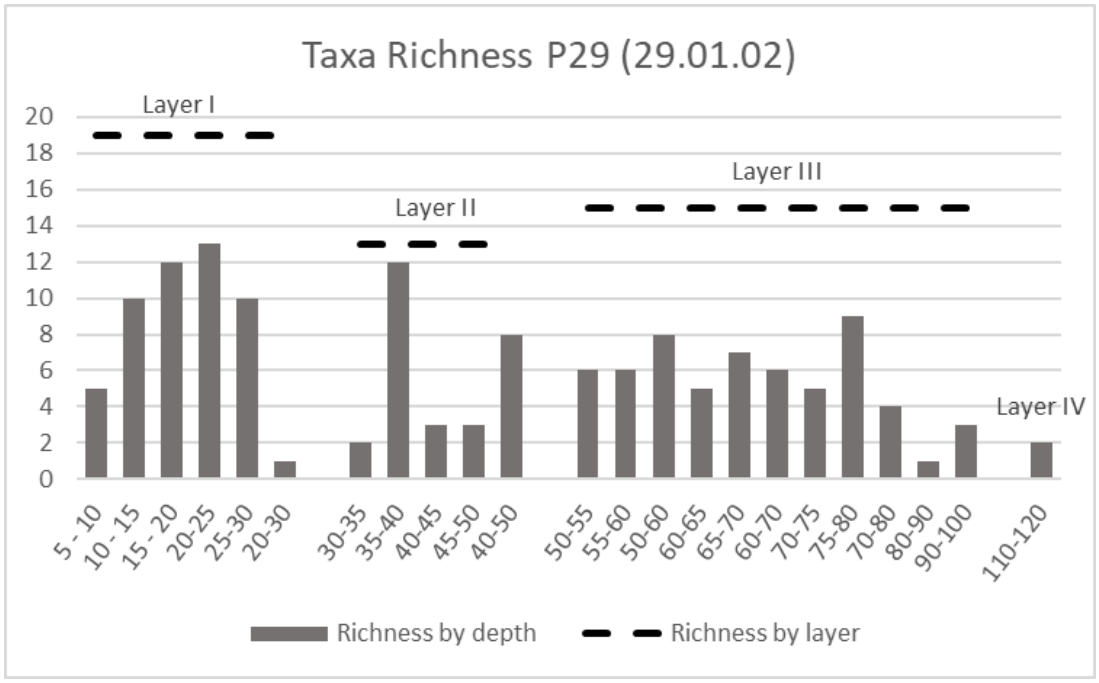


Figure 43: TP 29.01.02 taxa richness.

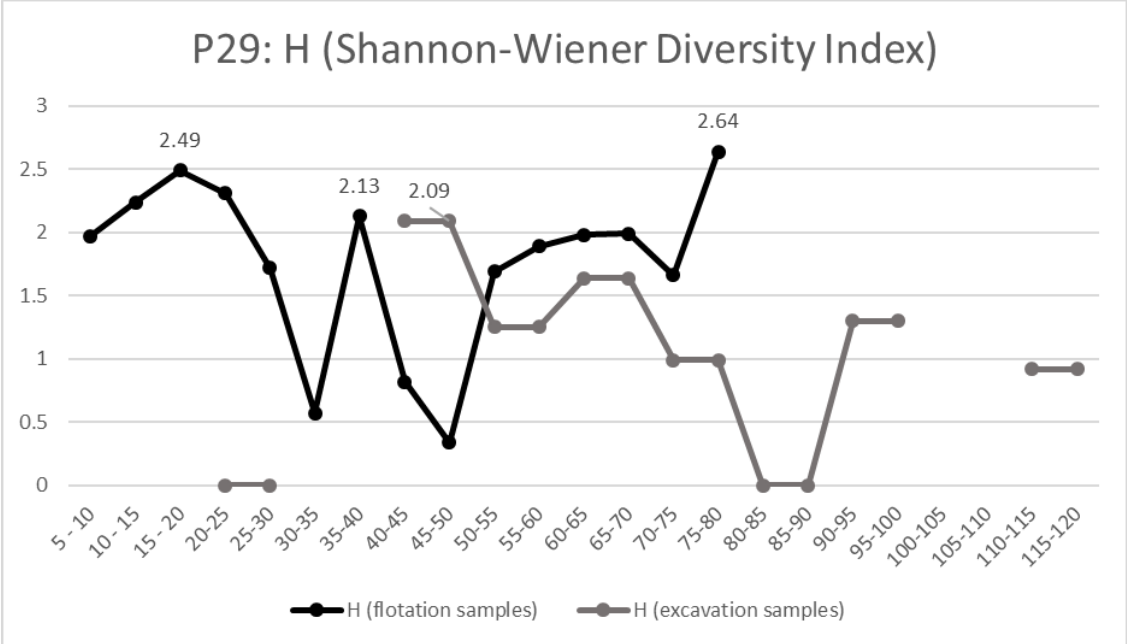


Figure 44: TP 29.01.02 H values per samples.

The most frequently identified taxon is Myrtaceae type A, as is the case with the P5 site. More than 60% of all the identified fragments corresponds to Myrtaceae type A, followed by *F. magellanica* (10.1%) and the Ericaceae family (7.6%). In terms of ubiquity (figure 45), Myrtaceae type A and *F. magellanica* show the highest ubiquity (95.1% and 73.1% respectively), followed by *Ribes* sp. and the Asteraceae family (both showing 46.1%). Other tree taxon with important representation is *Drimys winteri*, showing a frequency of 6.1% and ubiquity of 38.5%.

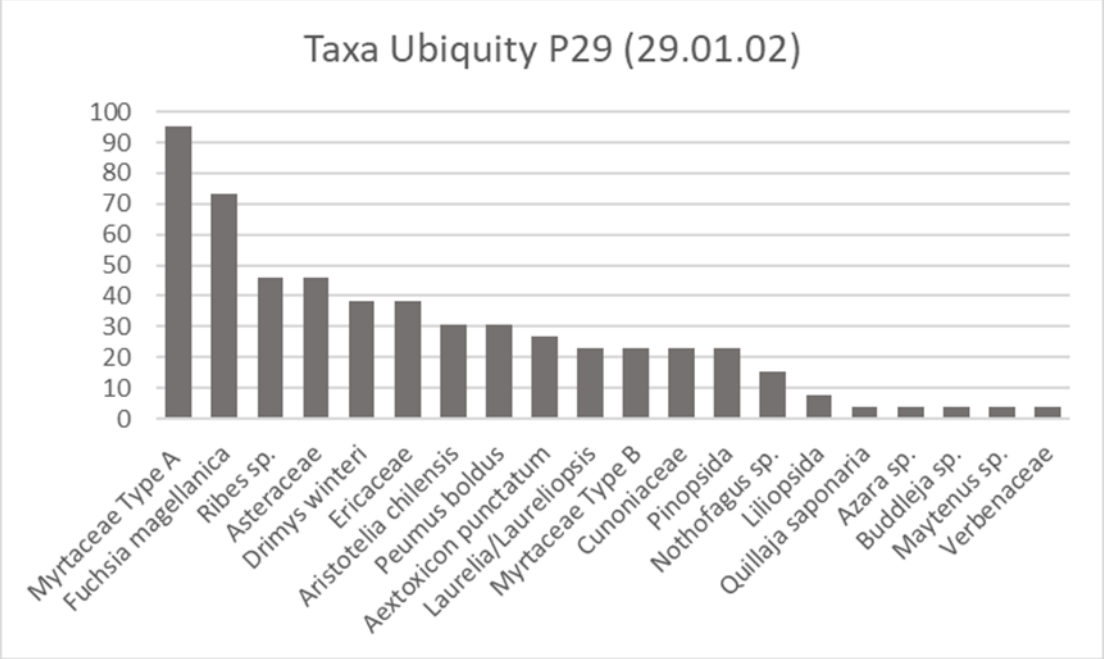


Figure 45: TP 29.01.02 taxa ubiquity.

In terms of relative frequency and only considering the flotation samples (figure 46), the Myrtaceae type A reaches high percentages (over 60%) between the 30 and 50 cm (Layer II). *Fuchsia magellanica*, the second most frequent and ubiquitous taxon shows higher percentage in the deeper samples (20% to 30%) than ones from the upper layers (10% to 15%), showing a clear difference between Layer III and Layers II and I. The shrub *Ribes* sp. follows a similar tendency to *F. magellanica*: a low representation in Layer II and I, and a more significant one in Layer III (although the percentages are much lower than the ones observed for *F. magellanica*). The Ericaceae family (also shrub taxa), shows higher percentages in the layer two (between the 35 to 45 cm).

Since there are no flotation samples available for the deepest levels of the sequence (over the 80 cm of depth), and the small sample size for Layer IV, taxa comparisons for these samples considers only presence and absence. The only taxa identified beyond the 80 cm are Myrtaceae type A, *F. magellanica, Nothofagus* sp., *Drimys winteri,* and *Peumus boldus*. While the first three taxa are also found in Layers I, II and III (until the 100 cm), *D. wintery* and P. boldus are the only two taxa to be identified in the four layers (until the 110-120 cm).

Even though of their low frequency, conifers and monocots are important to mention because they are not frequently found in the archaeobotanical record of the Island. Conifers in this site were only identified in Layer I (10-30 cm) and Layer III (60–75 cm), and Monocots only in Layer III (65-80 cm).

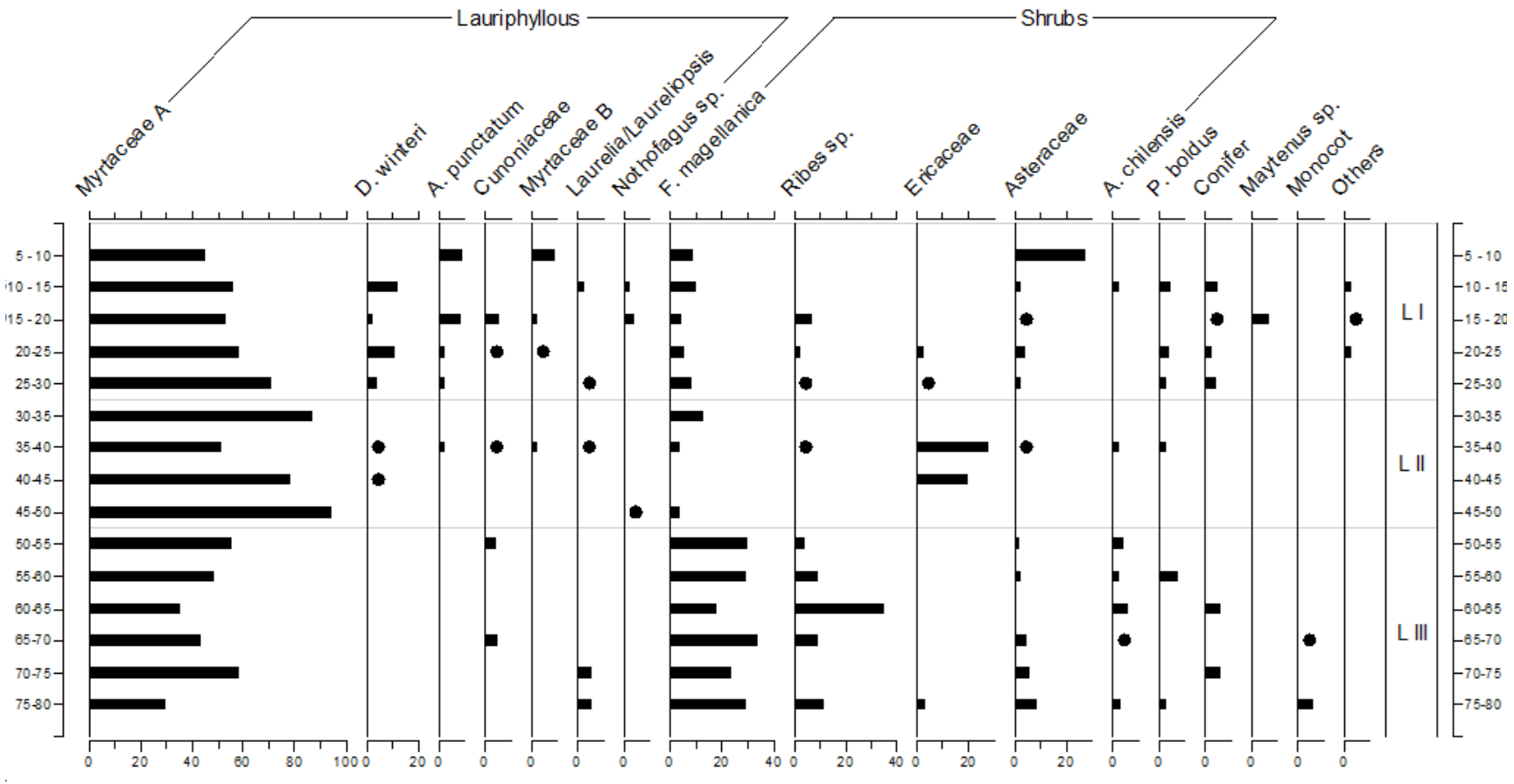


Figure 46: TP 29.01.02 wood charcoal taxa relative frequency from flotation column. Circles represent values under 2%.

7.3.3.2 Unknown taxa

Among the indeterminate 124 angiosperm fragments, there were two recurrent types observed in different samples assigned as Type B and Type C (description in appendix B). Type B was already registered in P5, and in P29 was registered in some of the samples between the 35 to 60 cm (table 12). Type C was recognized in some of the samples between the 45 to 80 cm, being most frequently registered in Layer III, particularly between the 50 and 60 cm

Table 12: TP 29.01.02 frequency of unknown types B and C.

Unidentified Fragments	Layer II				Layer III					Total
	35-40 cm	40-45 cm	45-50 cm	40-50 cm	50-55 cm	55-60 cm	50-60 cm	60-70 cm	75-80 cm	
Type B	1	2	1	2	1		1			8
Type C			2		15	17		2	2	38

7.3.3.3 Non-identifiable taxa

Among the 329 fragments categorized as non-identifiable, there is a high prevalence of alterations mainly related to taphonomic processes and anatomical issues. There are many fragments presenting more than one type of alteration (shown separately in and in table 13), but the values in this written section represent the sum of each alteration category as a percentage of the total of non-identifiable fragments. Taphonomic features where the most frequent present in 68.7% of the non-identifiable category.

The second most frequent registered features were related to anatomical issues such as knots (17.9%). Other anatomical issues such as small diameter/gauge were observed in lower percentages (4.3%). In a 14% of the assemblage, it was not possible to observe the three anatomical wood plains, and 6.4% of the fragments were too small to be identified.

Table 13: TP 29.01.02 detail of non-identifiable fragments.

Non-identifiable fragments	**N**	**%**
Presence of one or more taphonomic features	189	57.4
Fragments too small to be identified	15	4.5
Fragments too small to be identified and one or more taphonomic features	6	1.8
Alterations related to wood growth (compression/tension wood and knots)	33	10
Presence of one or more taphonomic features and alterations related to wood growth	26	7.9
Not possible to observe all anatomical sections	45	13.7
Small wood gauge (twigs)	10	3
Small wood gauge with presence of one or more taphonomic features	4	1.2
Not possible to observe all anatomical sections and presence of one or more taphonomic features	1	0.3
Total	**329**	**100**

7.3.3.4 Alterations in the wood anatomy of the assemblage

Along the sequence 76 fragments showed anatomical alterations registered as knots. They were mainly identified in fragments over 4 mm (9.7%), and almost a quarter correspond to big fragments over 8mm (23.7%). Most of the fragments presenting knots were categorized as non-identifiable (77.6%). Only five identified taxa showed knots in small frequencies (table 14).

Table 14: TP 29.01.01 detail of wood charcoal anatomical alterations.

Category		**N**	**%**
Identified	Myrtaceae	7	9.2
	Fuchsia magellanica	2	2.6
	Asteraceae	1	1.3
	Drimys winteri	1	1.3
	Ericaceae	1	1.3
Unknown		5	6.6
Non-identifiable		59	77.6
Total		76	100

7.3.3.5 Diameter measurements of the assemblage

Diameter estimations could not be conducted due to the fragmentation of the wood charcoal samples. Nevertheless, in 18 fragments it was possible to observe a complete diameter (less than 2 cm), indicating the preservation small gauge twigs in Layer I, II and III. Only four of these ten fragments were identified taxonomically, two as Myrtaceae type A, and two as *Fuchsia magellanica.*

7.3.3.6 Taphonomy of the assemblage

A total of 423 fragments showed at least one taphonomic feature, representing a 27.8% of the analysed wood charcoal fragments. The most frequent features registered were vitrification and combustion cracks (n=345, 22.6% of the site's wood charcoal total), both related the combustions process (figure 47, V =

vitrification, C= radial cracks). The presence of fungal and xylophage organisms was also observed (H= hyphae in figure 47), and in minor proportion other features such as structural collapse and infillings were also registered (Infillings= I, and others were groups as = O, in figure 47).

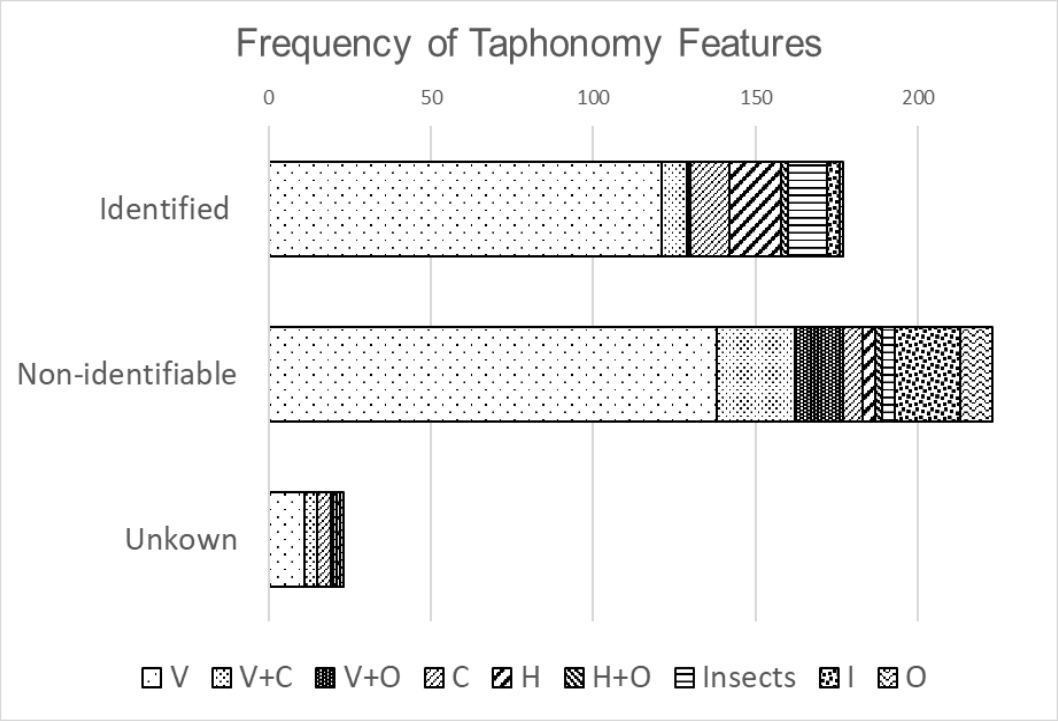


Figure 47: TP 29.01.02 frequency of taphonomic features (V= vitrification, C= radial cracks, H= hyphae, I= infillings, O= others)

Among the identified fragments, a 16.3% showed at least one taphonomic feature, while in the unknown category it reached 20.9% (figure 47). In terms of layers and depth, the highest percentage of fragments with taphonomic features was observed in Layer III between the 55 to 60 cm (38.2%) and between the 75-80 cm (39.1%). In most of the other samples, the percentage of fragments with taphonomic features fluctuates between 10% to 30 %, except

in the more deeper excavation samples where it reached around 50% (figure 48).

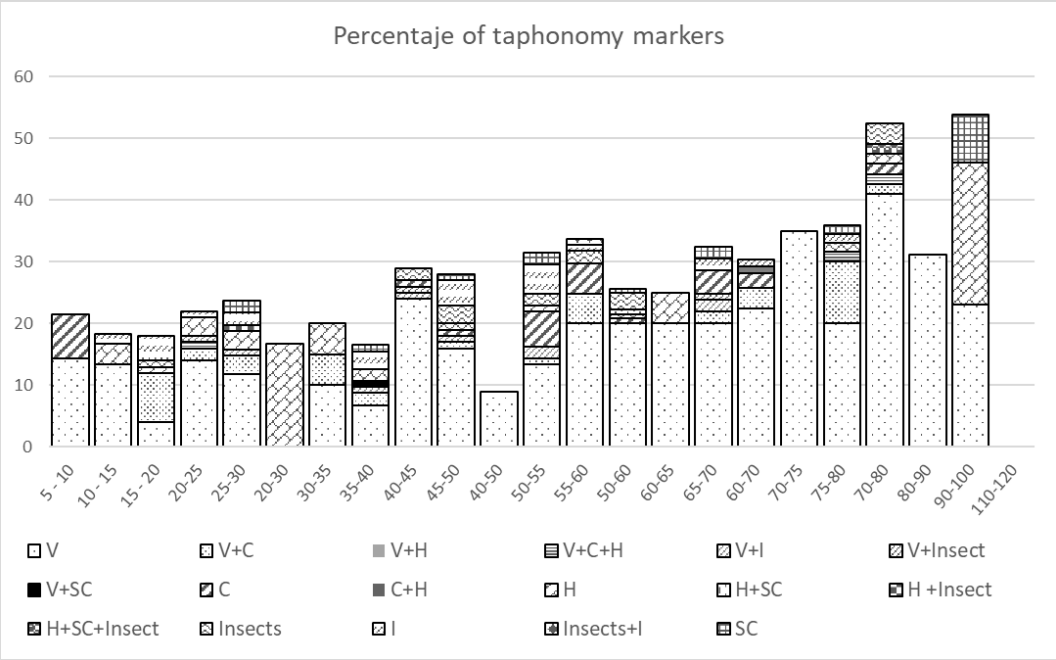


Figure 48: TP 29.01.02 percentage of taphonomic features (V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse)

Since a significant part of the fragments showed more than one taphonomic feature simultaneously (n=78), as well as in P5, the more frequent features are presented separately (vitrification and radial cracks), while the remaining ones were grouped in pairs.

Vitrification was registered mainly on its own (n=138, 9%), and in less proportion along with radial cracks, hyphae, and infillings (figure 49, details in table 10, appendix A). Among the identified fragments, the Myrtaceae type A presents the highest frequency of vitrification. Among the taxa showing

vitrification there are the ones with high frequency in the site´s wood charcoal assemblage (*F. magellanica* and the Ericaceae family), but also less common taxa such as *Nothofagus* sp. and monocots (figure 49).

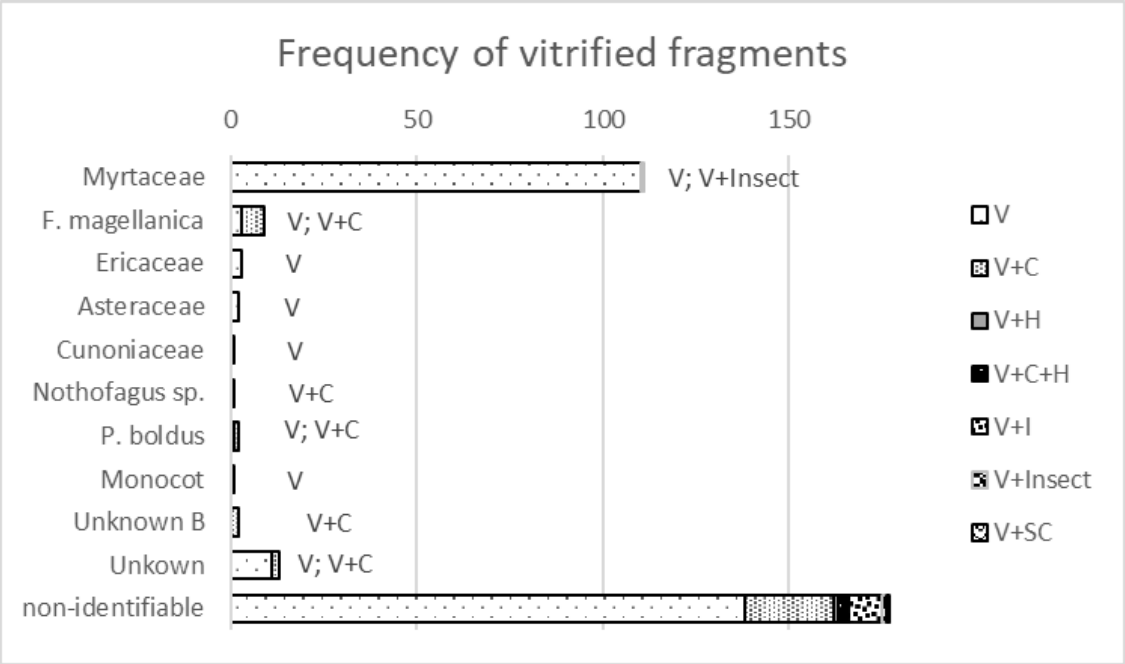


Figure 49: TP 29.01.02 detail of vitrified fragments (V: vitrification, C: radial cracks, H: hyphae, I: infillings).

Most of the fragments showing radial cracks also showed vitrification (figure 50, see details in table 10, appendix A). There are few identified fragments showing radial cracks (n=20), nevertheless, most of them correspond to taxa with wide cell rays (more than 3 rows of cells), such as *F. magellanica*, Ericaceae, Ribes sp., *P. boldus*, and Asteraceae, *A. punctatum* and *A. chilensis* (sum= 18).

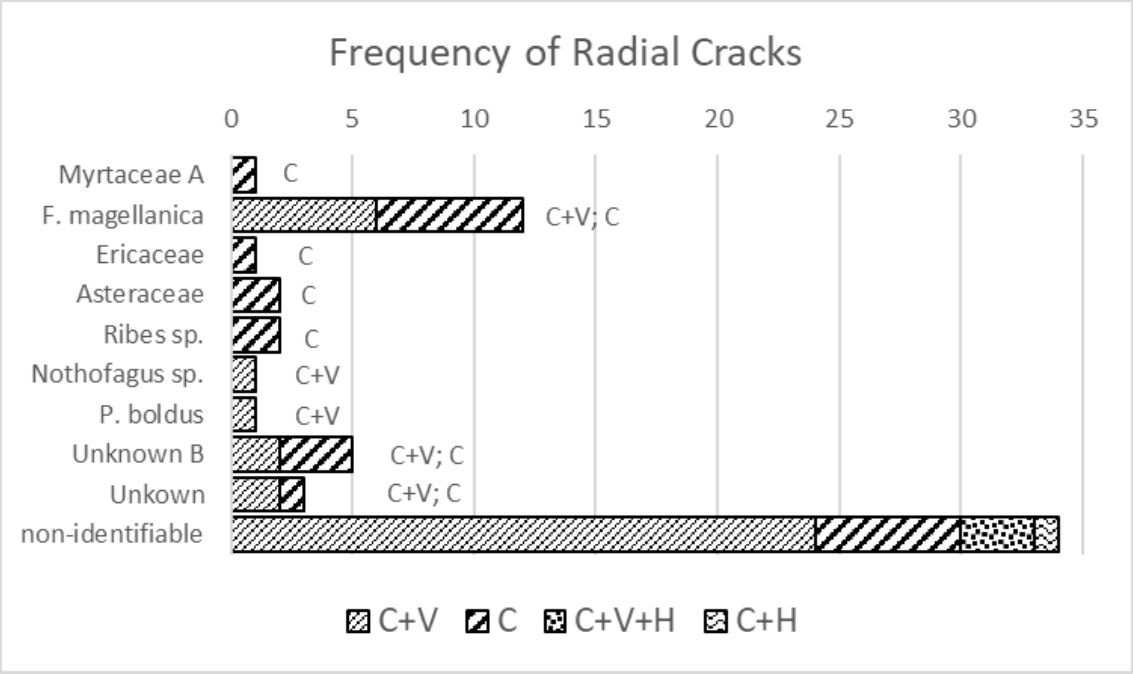


Figure 50: TP 29.01.02 detail of fragments with radial cracks (C: radial cracks, V: vitrification, and H: hyphae).

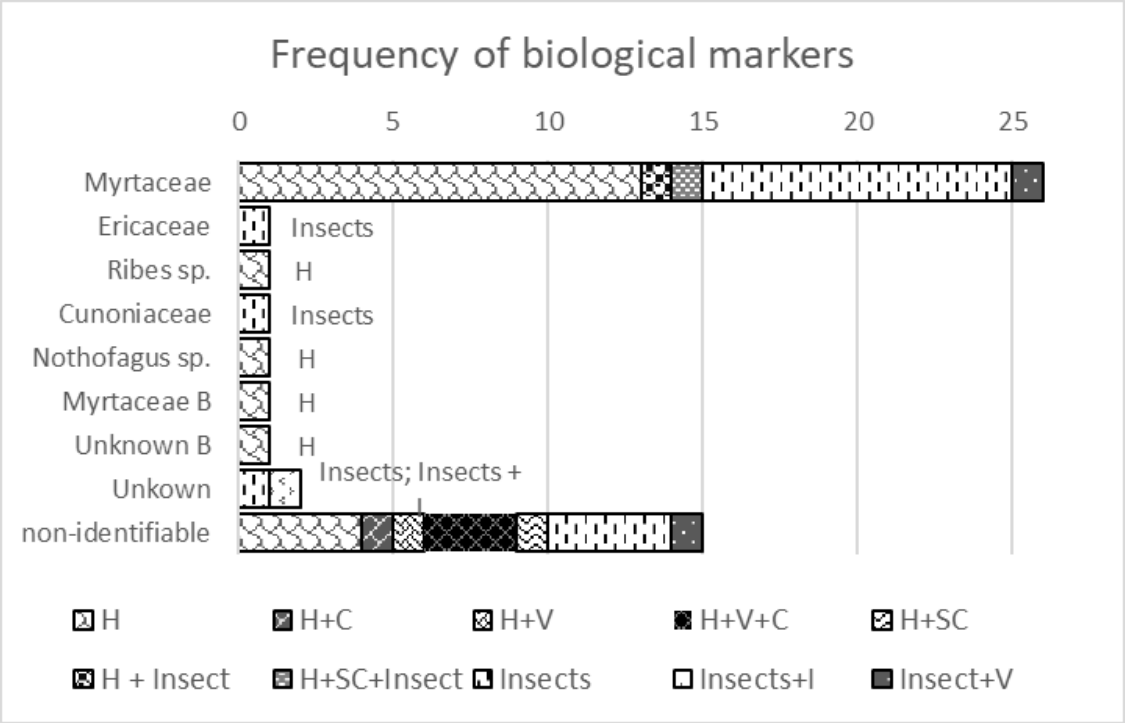


Figure 51: TP 29.01.02 detail of fragments with biological markers (H: hyphae, V: vitrification, C: radial cracks, I: infillings, SC: structural collapse).

Hyphae and indicators of xylophage insects were identified as biological markers of wood decay in 49 fragments (3.2% of the site's wood charcoal total). They were mainly identified separately on its own but also along taphonomic features related to the combustion process (vitrification and radial cracks). Although six identified taxa presented biological markers of wood decay (figure 51), only in Myrtaceae type A Hyphae and xylophage insects were registered simultaneously.

7.3.4 Integration of the results with previous archaeobotanical information of the site and the Island

The previous archaeobotanical analysis of the sites includes charred seeds and micro remains. Both remains were obtained from the same sediment column (TP 29.01.02). Similarly to P5, among the macro remains of the site there is a predominance of edible taxa. There were only four native woody taxa identified among the charred seeds: *Aristotelia chilensis, Luzuriaga radicans* Ruiz & Pav., *Ugni* spp., and *Gevuina avellana (*table 3, appendix A). The last species has an edible nut, and it was not identified among the wood charcoal fragments of the site (although fragments of the Proteaceae family have been identified in the P5 and P31). *L. radicans* is a climbing shrub with an edible berry, it was not identified among the wood charcoal fragments of the site, and apparently it has not been identified in any other site of the Island. While *A. chilensis* was identified in the wood charcoal record of the site, *Ugni* spp. could have been categorized under the *Myrtaceae* family category.

From the micro remains sample another woody-like taxon was identified: cf. *Chusquea* spp. (Roa 2016). This bamboo like plant could have been categorized under the monocots wood charcoal fragments. The young shoots of some species of the genus can be eaten raw *(Chusquea quila* Kunth and *Chusquea culeou* E. Desv.), and the seeds can be used to prepare flour (Cordero, Abello & Galvez 2017, Wilhelm de Möesbach 1992). Although wood charcoal fragments of monocots were also identified in P5, as a genus, *Chusquea* has only been identified in P29.

As also observed in the charred seed record, most of the identified taxa in the wood charcoal assemblage have reported edible parts (12 taxa). Among the edible taxa there are four that also have other reported ethnobotanical uses (medicine and dyes). Of the remaining seven taxa, seven have other reported uses and one was appreciated for its wood (table 23, appendix A).

7.4 Mocha Island: discussion of the archaeobotanical assemblage

Considering the samples analysed for this dissertation (TP 05.02.03 and TP 29.01.02), but also the previous wood charcoal results (TP 06.01.01 and TP 31.02.01, tables 7 and 11, appendix A), a total of 34 woody taxa were identified from the Ceramic Period of Mocha Island. These taxa represent 25 families of angiosperms, but also monocots and conifers. All the identified taxa correspond to native taxa of Southern Chile, but among them, there are species described as non-native to Mocha Island (conifers and the *Nothofagus* genus, LeQuesne, Villagrán & Villa 1999).

In order to facilitate the discussion and estimate a broader image of the forest environment of the Island, the taxonomical results from all the sites were grouped in temporal consecutive phases of 200 years (figure 52). Nevertheless, the first phase is less than 200 years because there are no earlier dates than around the 850 CE. At the other end, the latest phase is more than 200 years because we know the island was depopulated in 1687 and some of the radiocarbon dates are not far from this year (table 12, appendix A), so for practical reasons it was convenient to extend the last phase until the Island depopulation.

For the first phase (pre 1000 CE: from around the 850 to 1000 CE) we only have the data from TP 05.02.03 (Layer IV, 100-110 cm). Since the sample size of this phase is small (27 identified fragments), the taxa percentages are not reliable in statistical terms. The most frequently identified taxa in this phase are *A. punctatum, P. lingue, Laurelia/Laureliopsis* and *F. magellanica.*

The next phase was established between the 1001 and 1200 CE and considers the data from TP 06.01.01 (Layer IV, 90-110 cm), TP 29.01.02 (Layer IV and Layer III, 80-120 cm), and TP 31.02.01 (Layer IV, 80-100 cm). This phase has a small sample size (139 identified fragments), and the most frequent taxon is the Myrtaceae family (33.8%). Similarly to the previous phase, taxa such as *P. lingue* (10.8%), *Laurelia/Laureliopsis* (10%), *A. punctatum* (7.2%), and *F. magellanica (*6.5%) were identified. Other tree taxa found in this phase is the Cunoniaceae family (9.3%), *P. boldus* (4.3%) and *D. winteri* (2.2%).

For the phase between the 1201 and 1400 CE there are 2,381 identified fragments that includes data from all the sites. The Myrtaceae family is the most frequent taxa (46.4%, considering together type A and B). The second most frequent taxon is *F. magellanica* (10.4%). All tree taxa mentioned in the earlier phases show smaller percentages in this phase, the exception are *P. boldus* (showing a slighter higher value of 6.8%) and *D. winteri* (showing a similar value of 2.6%).

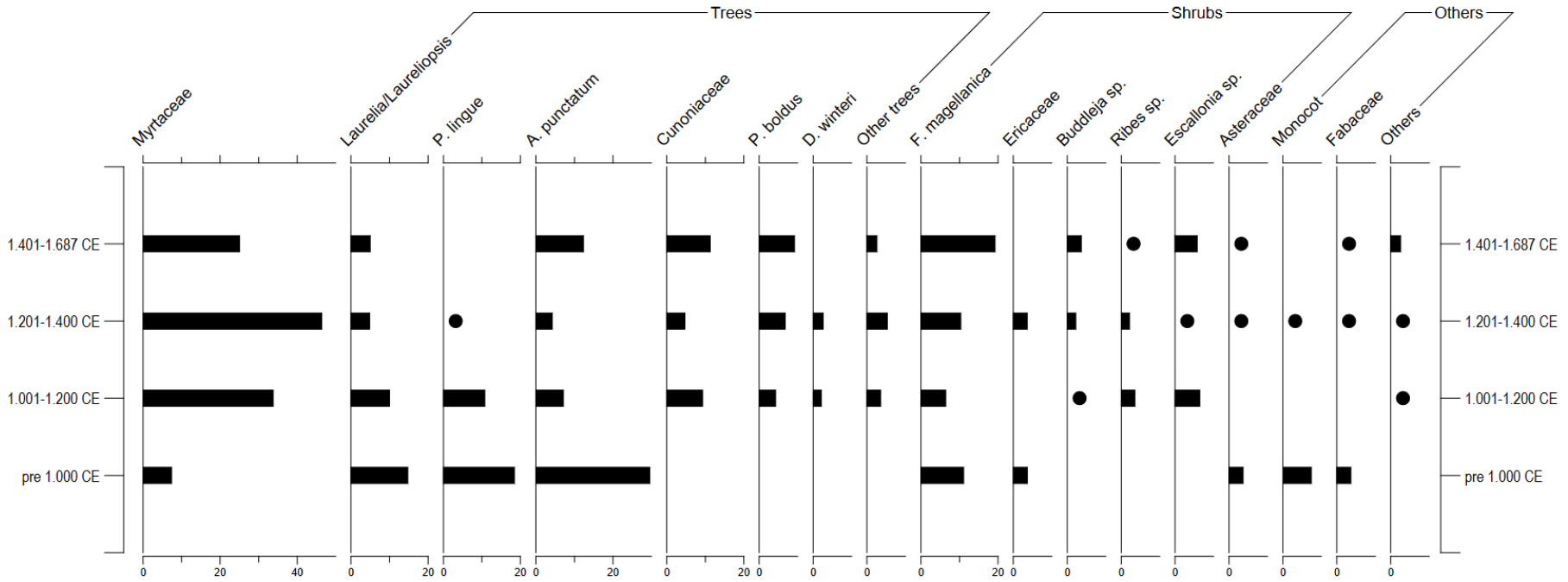


Figure 52: Summary of Identified Woody taxa from P5, P29 and P31.

For the last phase between the 1401 and 1685 CE, there is a sample of 379 identified fragments all from TP 31.02.01 (Layer I and II, 20-60 cm). While Myrtaceae is still the most frequent taxon (25%), its percentage is lower than in the previous phases. *F. magellanica* continues to be the second most frequent taxon but shows a higher percentage than in the previous phases (19.3%). The other tree taxa show higher percentages in relation to the previous phase: *A. punctatum* (12.4%), Cunoniaceae (11.3%), *P. boldus* (9.2%), and *Laurelia/Laureliopsis* (5%).

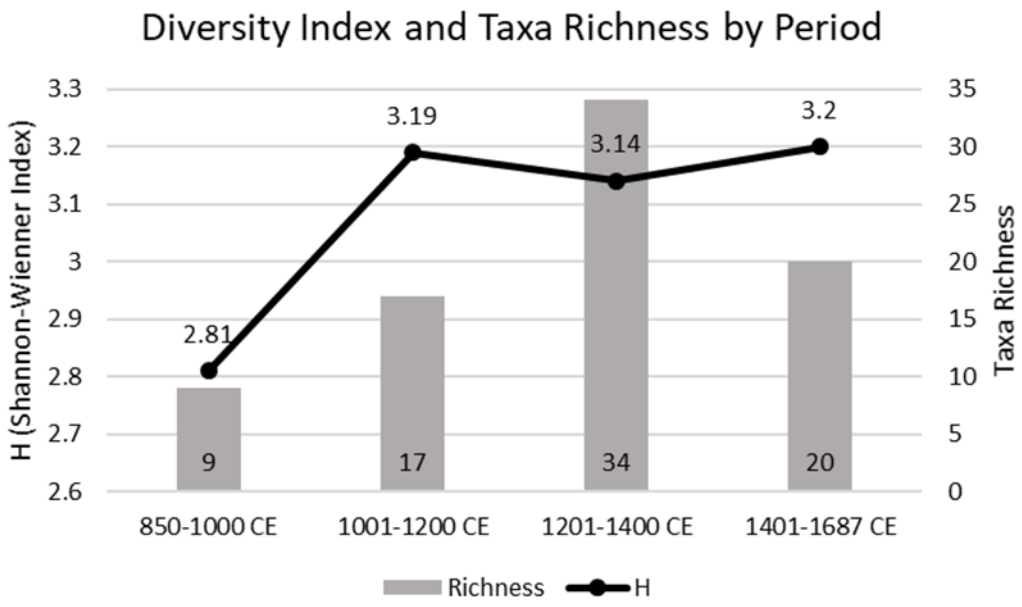


Figure 53: H (Shannon-Wienner index) and taxa richness by phases.

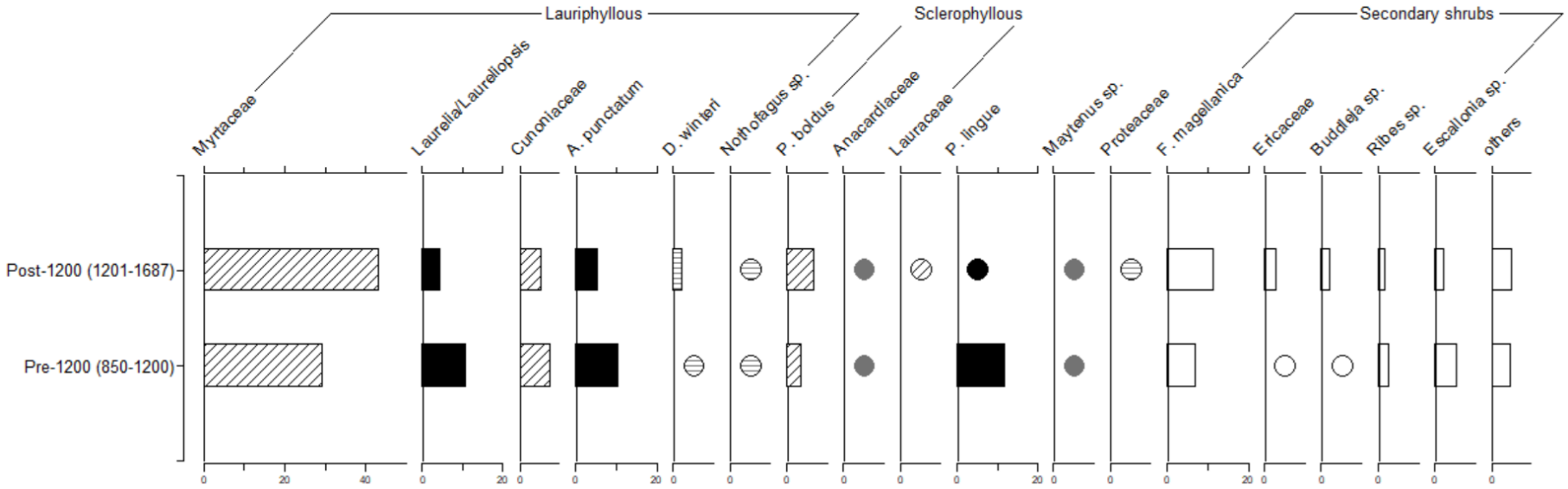


Figure 54: Sumary of Identified Woody taxa from P5, P29 and P31 according to ecology. Black filling indicates shade tolerance (Laurelia/Laureliopsis, A. punctatum, and P. lingue); striped diagonal filling indicates shade tolerance to medium tolerance (Myrtaceae, Cunoniaceae, P. boldus and Lauraceae); striped horizontal filling indicates shade intolerance to medium tolerance (D. winteri, Nothofagus sp. and Proteacea), grey filling indicates shade intolerance (Anacardiaceae and Maytenus sp.). Unfilled or white colour indicates no specific shade/light tolerance. Circles indicates values under 2%.

In comparison, the highest taxa richness was registered in the 1201-1400 phase (n=34, figure 53). In terms of diversity, the H values (Shannon-Wienner Index) are similar in the three later phases (1001-1687 CE), which is interesting considering that these phases show different taxa richness values. The low H and richness values of the first phase (800-1000 CE) could be explained by the small sample size.

From an ecological perspective, the results indicate presence of lauriphyllous and sclerophyllous species, as well as secondary shrubs (figure 54). Taking in consideration the taxa similarities observed among the two early phases (from around 850 to 1200 CE), and the two later ones (from 1201 to 1687 CE), the results were regrouped in two phases. In order to explore possible changes in the vegetation types, and for comparison purposes some species were grouped together under the family identification (for instance *Cryptocarya alba* was grouped under Lauraceae, Myrtaceae type A and B were grouped together as Myrtaceae). Although this helped to standardize the taxa among the different sites, it has the disadvantage of a less accurate environmental interpretation. But since most of the assemblage was identified at a family level (Myrtaceae), this limitation was one already existing in the data set. The taxa were classified according to their ecology, shade tolerance and primary or secondary status in forest succession using relevant published literature (Donoso 2006, Gutiérrez & Huth 2012, Luebert & Pliscoff 2006, Lusk & Del Pozo 2002, Lusk 1996). Most of the secondary shrubs and some tree taxa (*P. lingue* and *Maytenus* sp.) show a broad ecological spectrum, being found in both forest associations, so they were not classified under sclerophyllous or

lauriphyllous types. The Proteaceae family was also not classified under those categories, because it encompasses species with broad ecological distribution.

In general terms, the lauriphyllous taxa dominates the assemblage in both phases: 61.4% in the earlier phase and 62.2 % in the later one. Sclerophyllous taxa were more represented in the post-1200 phase (9.5%) than in the pre-1200 Phase (4.2%). Secondary shrubs show a slight increase in the later phase (from 16.9% in pre-1200 phase to 21.7% in the post-1200 one).

In terms of shade tolerance and forest succession, the pioneer taxa are usually shade intolerant and able to grow in poor soils while late successional taxa are shade tolerant and require fertile soils (Gutiérrez & Huth 2012, Lusk & Contreras 1999). The shade tolerant taxa (*A. punctatum*, *Laurelia/Laureliopsis, and Persea lingue)*, represent a 33.7% of the identified taxa in the phase before the 1200 and a 10.6 % in the phase between the 1201 – 1687 CE. Then, among the shade tolerant to medium tolerance we can count the Myrtaceae, Cunoniaceae, and Lauraceae families (both encompassing shade tolerant species and medium tolerance to shade species), and *P. boldus*. If we grouped these taxa with the previous shade tolerant ones, we still observe a decrease in the shade tolerant species in the later phase (from 75.3% in the pre-1200 phase to 67.9% in the post-1200 phase). At the other end of shade tolerance spectrum, we find two shade intolerant taxa (Anacardiaceae and *Maytenus* sp.) and three shade intolerants to medium tolerant taxa (*D. winteri*, *Nothofagus sp.* and Proteaceae*).* Altogether these taxa represent just 3.6% in prior to 1200 CE phase and 4.8% in the post 1200 CE phase. This could be interpreted as an

exploitation of mostly established woodland, and to a lesser degree, the use of forest edge taxa.

Secondary shrubs show also adaptability to shade conditions, but they have been associated with fire disturbance. Once the secondary shrubs are established in Mocha Island, it is difficult for trees such as *A. punctatum* to regenerate (LeQuesne, Villagrán & Villa 1999).

If we compare the charcoal phases with the available pollen evidence of the Island (ibid.), the main difficulty is the lack of ^{14}C dates for the pollen sequence. There is only one ^{14}C date obtained at the beginning of the Laguna Huairavos sequences (126-525 cal. CE, see details in table 12, appendix A), that fits into the Early Ceramic Period of the Island. In this pollen zone there is a predominance of woody taxa such as *A. punctatum*, Myrtaceae, *Hydrangea serratifolia*, an *Azara sp*. type, and some traces of *Eucryphia cordifolia*. Later pollen zones show lower percentage of woody taxa with an important presence of grass like plants, all indicative of a disturbed environment (Lequesne, Villagrán & Villa 1999). Since there are no dates for the others pollen zones, it is difficult to link these changes to the archaeological periods. Nevertheless, it is interesting that some non-native taxa to the Island such as Conifers and the *Nothofagus* genus appear also in the pollen record (*Nothofagus* type *dombeyi*, and *Podocarpus nubigena* Lindl.). Although this was interpreted as pollen from the continental coast (apparently both species have high pollen dispersion values), the fact that wood charcoal from compatible taxa was identified in the Island open new interpretative possibilities. If we agree that neither the

Nothofagus genus or conifers were native to the Island, the identified wood charcoal could represent driftwood, or wood pieces carried to the Island during pre-Hispanic times. Since the pre-Hispanic populations were introducing animals (like *Pudu puda* and camelids, among others), but also plants (*Zea mays, Phaseolus* sp., *Chenopodium* sp.), they could have also introduced woody plants. For other taxa such as the Anacardiaceae family there were no previous record in the ecological descriptions of Reiche or Kunkel (table 4, appendix A). Nevertheless, *Lithrea caustica* was found in the pollen record, *Schinus* was identified among the wood charcoal and the charred seeds registered as cf. Anacardiaceae all suggest the presence of the family in the Island since pre-Hispanic times.

The rest of available archaeobotanical evidence (mainly from charred seeds), suggest that quinoa was the most relevant vegetal food in the Ceramic Period (Roa et al., 2021), and probably the first cultivated plant to be introduced to the Island during the Early Ceramic Period. Other crops such as maize and beans appear later (post-1000 CE), at the same time that camelids become abundant in the zooarchaeological record. Although there are no taxon dates, berries are ubiquitous and frequent in the archaeobotanical record. Since most of these berries are woody species (excepting *Rubus geoides* Sm. and *Fragaria chiloensis*), it is interesting to compare its presence/absence in the wood charcoal versus the charred seed record. *Aristotelia chilensis*, Myrtaceae, Polygonaceae are taxa found in both records. Ericaceae and *Ribes* sp. were only found as wood charcoal fragments and there is no record of their seeds in the Island. Finally, *Cissus striata* Ruiz & Pav. was identified among the charred

seeds but not with certainty among the wood charcoal record (categorized as cf. *Cissus striata* in TP 06.01.01 and TP 31.01.02). There are also other taxa such as *Lapageria rosea, Luzuriaga radicands* and *Coriaria ruscifolia* that were identified among the charred seed records and not among the wood charcoal remains (although *C. ruscifolia* is poisonous). Since most of these species bloom around spring, their fruits are ripe by summer and early autumn (December to March/April, Cordero, Abello & Galvez 2017, Muñoz, Barrera & Meza 1981). At the moment is not possible to estimate if seasonality might be affecting the taxa representation in both of the archaeobotanical assemblages opening questions such as: are berries being collected along with firewood? Are certain woody species used as fuel after their fruit bearing season? Are certain woody taxa avoided as firewood? Another aspect to consider is the fact that two of the species found among the seeds but not in the wood charcoal are climbing shrubs (*Lapageria rosea, Luzuriaga radicans* and *Cissus striata*). This opens the possibility of poor preservation of vines and other types of woody climbers because of its wood anatomy: features such as grouped pores and wide cell rays can promote fragmentation (Chrzazvez *et al.* 2014). Other woody species with edible fruits (*Cryptocarya alba*, Anacardiaceae), and nuts (*Gevuina avellana*) were found among the charred seeds and the wood charcoal (but usually under different identifications levels).

Finally, when comparing beyond the taxa similarities of the obtained results with the previous wood charcoal analysis, some differences were observed. As shown in table 15, the percentages of each identification category are similar in P29 and P31. While both sites show just over 70% of identified taxa, in P5

the identification rate was lower (around 65% in TP05.02.03 and 50% in TP 06.01.01). A correspondence analysis conducted with the samples of TP 06.01.01 and TP 31.02.1 (Delgado 2017) suggested that occurrence of taphonomic features was not related to the non-identifiable category. Nevertheless, since the analysed fragments were randomly selected in TP 06.01.01 and TP 31.02.01 (and fragment size was not recorded), it is not possible to evaluate if the differences in identification rates can be link to the fragmentation of the samples.

Related to this last issue, it is relevant to mention that this difference in the sampling strategy might also be affecting the percentages of taphonomic features. While in the previously analysed samples the biological indicators of wood decay were the most frequently registered (xylophagous organisms), the taphonomic features related to the combustion process (vitrification and radial cracks) were the most registered among the samples analysed for this dissertation. Although this could be explained by other factors, like differences in wood collection strategies, seems important not to discard a sampling explanation, keeping also in mind that previous analysis only contemplated flotation samples and no excavation samples.

Table 15: Comparison of main identification categories by Mocha Island's archaeological sites.

Identification Category	P5 Site				P29 Site		P31 Site	
	TP 05.02.03		TP 06.01.01		TP 29.01.02		TP 31.02.01	
	N	%	N	%	N	%	N	%
Identified	615	64.7	665	50.3	1084	71.2	620	71.3
Unknown	132	13.9	108	8.2	124	8.1	86	9.9
Non-Identifiable	204	21.4	549	41.5	315	20.7	163	18.8
Total	951	-	1322	-	1523	-	869	-

7.5 Summary of Mocha Island results and interpretation

From the three sites considered, a total of 34 native woody taxa were identified that includes trees, shrubs and other minor wood like plants, of lauriphyllous and sclerophyllous types. Although they are all native to southern Chile, two of them have been described as non-native to the Island (*Nothofagus sp*. and conifers). The most frequent and ubiquitous taxon in all the sites is Myrtaceae type A, a family that includes trees and shrubs with edible berries. In ecological terms, some species of the Myrtaceae family have been described as components of the intermediate stage of forest succession (Lara *et al.* 2014).

In terms of chronology, most of the wood charcoal assemblages from the sites was concentrated between the 1200 -1400 CE. Although the sample size for the previous centuries is reduced, some trends were observed: shade tolerant species seem to decrease their representation over time, while secondary shrubs show a slight increase.

The identified taxa indicate a combination of both shade tolerant and shade tolerant species, as well as secondary species. There is no evidence to suggest a predominance of a closed canopy forest but neither a complete deforested landscape during the Late Ceramic Period in Mocha Island. Probably, in the central part of the Island an old growth forest could have persisted (providing seeds, wood, and other resources from shade tolerant species), while in the plains, where all the residential units were concentrated, a more open type of vegetation could have been established.

Chapter 8: La Cueva de Los Catalanes

8.1 Geographical and Archaeological Context

"Cueva de los Catalanes" archaeological site (WGS84, UTM 18H 725638E, 5812890S) is a sandstone cave located in the Malleco Province, Araucanía Region. From a broad geographic perspective, the location of the site corresponds to the Vergara River sub-basin and the current tributary stream, the Renaico River, is only 800 m away from the cave (Campbell, Roa & Santana-Sagredo 2018). Since the 1980's a significant percentage of the land surface of the Malleco Province has been turned into forestry plantations of exotic taxa. Although the surroundings of the site are dominated by exotic tree plantations (mostly *Pinus radiata* and *Acacia dealbata*), there are some remaining patches of native flora along the main access road to the site. The native vegetal species identified during field visits (table 13, appendix A) are characteristic of a transition between sclerophyll forest (drought-tolerant species and open canopy) and seasonal temperate rainforest (shade-tolerant species and closed canopy). These field observations are in correspondence with the general native vegetation descriptions of the Araucanía region (Abarzúa *et al.* 2014, Luebert & Pliscoff 2006).

The archaeological site was previously excavated in 1956 by archaeologists from the Universidad de Chile. Prior to the excavation, the cave was part of a private farm called "Fundo Los Catalanes" (hence the name of the site). Since the publication (1968), the site has been known as "Cueva de Los Catalanes" (*cueva* means cave), even though "Los Catalanes" farm was divided, and the

cave was part of “Fundo El Peñón” since before its first excavation. Cueva de los Catalanes is an emblematic archaeological site of the Araucanía region because its excavation gave the first stratigraphic sequence of the Ceramic Period and is the only known cave site in the longitudinal valley with rock art (Aldunate 1989, Campbell, Roa & Santana 2018).



Figure 55: Entrance view of “Cueva de los Catalanes”, author’s photograph (August 2016).

According to Berdichesky (1968), the cave was product of the eroding action of underground watercourses, which fragmented the sedimentary layers of the hill where the cave stands. Nowadays, right outside the cave runs the Biobío Sur canal, and a short bridge must be crossed to enter the cave (figure 55).

The construction of the Biobío Sur canal started in 1945, so it already existed during the 1956 excavation (Menghin 1962).

The cave is about 33 meters deep (E-W orientation, figure 56), and its high varies from 5 to 3 m at the main entrance and 2 to 0,5 m at the end (Campbell, Roa & Santana 2018). The cave was not used for the last ten years, but until a few decades ago used to serve as a corral for animals (mainly sheep). According to the 1956 excavation report, it was also used to store straw, and there was a fire not long before the first archaeological excavation. The walls of the cave would have acquired the black colour observable today after fire, although it is likely that they have been black from much earlier.

As part of the research archaeological project FONDECYT 11150397, the site was relocated in February 2016 and excavated during September of the same year. The materials studied in this thesis were recovered in 2016, but in order to give an overview of the site the following sections synthesize both of the excavation seasons.

8.1.1 The 1956 excavation

The main report of the excavation was published in 1968, by Bernardo Berdichewsky, who was part of the Centre of Anthropological Studies of the Unversidad de Chile (*Centro de Estudios Antropológicos*). The excavation of the site was part of an archaeological expedition to the Araucanía Region, and the Universidad de Chile invited Professor Osvaldo Menghin from the

Universidad de Buenos Aires to lead the expedition. Menghin published a preliminary summary of the excavation in 1962 and suggested a possible ritual use of the cave since food waste remains were not abundant (meaning bones and not vegetal resources). He also mentions the recovery of some early Hispanic materials from the 16th century, and later ones from the 18th and 19th centuries (Menghin 1962, p. 71-72). (Menghin 1962). Proffesor Menghin proposed four cultural phases (Horizontes culturales A, B, C, and D). Phase A corresponds to 18th and 19th centuries (*Siglos XVIII* and *XIX*, based on the presence of European materialities), phase B corresponds to the 16th century (*Siglo XVI*), phase C represents an Inca Period (*época de la invasion incaica*), and phase D a pre-Inca period (*preincaico*).

According to the excavation report, four excavation units along with small test pits were realized during the 1956 fieldwork. The material recovered corresponds to ceramic and lithic material, bones, some artefacts (mainly made of bone) as well as some Historic materials. A few human remains were also recovered, and although some hearth and fire features were recognized during the excavation, archaeobotanical samples were not collected (Berdichewsky 1968). The rock art corresponds to geometrical design carved into the sandstone walls of the cave and has not been possible to assign to a particular archaeological Period. Although no dating methods were used back when the site was excavated, the site was initially believed to be no older than 1000 CE. Berdichewsky recognized six different layers (*estratos* 0, I, II, III, IV, and V), and proposed four phases: an Early Ceramic Phase *(Alfarero Temprano* around the 1100 CE, Layers I and II), Late Ceramic Phase (*Agroalfarero*

Tardío, around 1400 CE, Layer III), Post-Late Ceramic Phase (*Post El Vergel,* around 1550 CE, Layer IV), and a Colonial Phase (around 1700 CE, Layer V,1968, p. 72-73).

Although most of the materials from the 1956 excavation were kept in the archaeology deposit of the Universidad de Chile, some of the artifacts that appear in the publication were not found (bone artefacts and grinding stones).

8.1.2 The 2016 excavation

In order to locate part of the previous excavations units and obtained a better stratigraphic control of the archaeological deposit, three test pits of 1X1m were done inside the cave, and one outside it. A complete register of the rock art on the cave walls was done during the 2016 fieldwork as well as a topographic record of the entire cave (Campbell, Moya & Gutiérrez 2020, Campbell, Roa &Santana-Sagredo 2018). The materials recovered from the 2016's excavation consisted of faunal, human and botanical remains, as well as ceramic, lithic, and other post contact materials. Thermoluminescence and AMS radiocarbon dates were obtained, indicating an occupation from 570 CE to 1800 CE (Campbell, Roa & Santana 2018, Campbell *et al.* 2020, Roa *et al*. 2018). These dates indicate that the cave was occupied during the Early Ceramic (570-1000 CE), Late Ceramic (1000-1550 CE) and Historic Period (1550-1800 CE).

The archaeological material was analysed according to current analytical methodologies (taxonomic and taphonomic approaches in the case of faunal,

human and botanical remains, and technological and functional approaches in the case of ceramic and lithic materials). Is relevant to mention that many of the results have not been published yet and most of the available information has been obtained from analysis reports and unpublished dissertations.

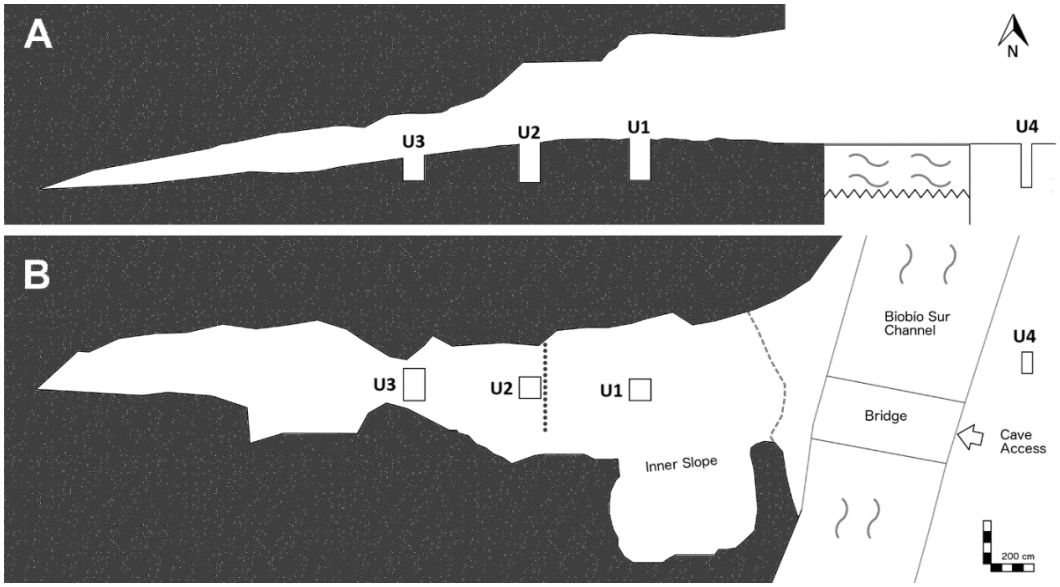


Figure 56: Cross section view and floor plan of Cueva de los Catalanes. (Modified from Roa 2018, A: cross section view of the cave, B: floor plan of the cave)

The taxonomic analysis of the faunal remains indicates the presence of mammals (97%), amphibians (2.8%), and birds (0.31%). The small mammals are the most represented faunal remains in the site, particularly rodents (86.7%), which is not surprising in a cave since other agents of bone accumulation were identified (fox, owls and other raptors). Small mammals such as Marsupials were also recognised (0.03%), and medium to bigger mammals were identified in less quantity. Among them, the guanaco (*Lama*

guanicoe) is the most represented big mammal, followed by the fox (*Lycalopex* sp.). The other identified species are: *Canidae, Conepatus chinga, Myocastor coypus*, and *Pudu puda*. Post contact animal, such as *Box Taurus, Capra hircus, Equus caballus* (Zúñiga 2021), were also registered in the site, but is uncertain if they correspond to the 17th - 19th centuries, or to the more recent period when the cave was used as corral. Among the amphibians, most of the remains were identified to order level (Anura), and the only identified species was *Calyptocephalella gayi (*commonly known as helmeted water toad or Chilean helmeted bull frog*)*. The few recovered bird remains includes taxa from terrestrial and aquatic environments. Although cut marks were identified only in medium to big size mammals, it is not possible to discard the consumption of some of the other small fauna registered in the site, such as small mammals or amphibians. Finally, some of the cut marks registered in fox and chinge (*C. chinga*) indicate the obtention of fur as well as butchering marks. The only two bone artifacts recovered in the site support the processing of fur/hide in the cave (Inostroza 2017).

Among the lithic assemblage, there is a hight percentage of scrapers and perforators, suggesting the processing of soft materials such as leather or vegetable fibres. Stone celts were also recovered, suggesting the work of woody materials. In less proportion, other instrument related to the hunting and processing of animals were also recovered. The presence of lithics with polished edges motivated an initial experimentation plan to evaluate the use of stone artefacts in relation to the rock art of the cave (Peñaloza & Guitiérrez

2021). These results were not conclusive, suggesting a necessity for a proper experimentation plan.

The ceramic assemblage recovered in 2016 is only composed of fragments (including parts of smoking pipes), and it shows diagnostic ceramic types of the ECP and LCP. Among diagnostic ceramic types of the ECP some smoked and incise decoration was registered and among the LCP fragments some white paint decoration was also registered. One of the particularities is the presence of ceramic fragments that show a significant wear in one of the borders. Even though the functionality of these fragments is not clear, as well as with the lithic assemblage, it was suggested that they could have been used to carve the sandstone walls of the cave (González 2018), and other possible uses include leather scrapers or ceramic smoothers.

Although the archaeobotanical materials will be discussed along with the wood charcoal results, the earliest taxon date of *Phaseolus vulgaris* of Southern Chile was obtained in the site (680-861 cal. CE, Campbell, Roa & Santana-Sagredo 2018). As well as in Mocha Island, the charred seeds show the consumption of cultivated plants and native wild species (Roa *et al.* 2018). Among the first group there is evidence of maize, quinoa, *Capsicum sp*. and *Madia sativa*, and among the wild taxa there were berries (*Aristoletia chilensis, B. trifoliata, M. hastulata, Ugni sp*.), fruits (*Cryptocarya alba),* nuts (*Gevuina avellana*) and other wild herbs (Roa Solís *et al*. 2024). The archaeobotanical record also shows the presence of *Triticum sp.,* crop that was introduced to southern Chile by the Spaniard conquerors (post 1550 CE).

In comparison, the preliminary results indicate more density of materials in U2 (recovered materials in relation to excavated volume), nevertheless, an important amount of the recovered materials correspond to rodent bones. If only lithic and pottery fragments are considered, in both units the higher density of materials is found between the 120 and 180 cm.

8.2 Material provenience and stratigraphy

Archaeobotanical remains were mainly recovered through flotation technique, but also some samples were handpicked during the excavation. In Unit 1 (hereafter, U1), flotation samples were taken systematically through a sediment column, but in unit 2 (hereafter, U2), few flotation samples were obtained, and they had different volumes.

In order to get comparable results with the Mocha Island sites, the sediment column dimensions were kept the same (25x25 cm). Nevertheless, the samples were obtained every 10 cm rather than every 5 cm, so the average volume of the flotation samples from the sediment column was 6.24 litres. In total, 20 flotation samples from U1 and four flotation samples from U2 were collected.

Each sediment sample was processed individually using a asisted flotation machine. The resulting light and heavy fraction were left to dry in a temperature-controlled room (Archaeology laboratory facilities of the Pontificia

Universidad Católica de Chile). Once dried, the light fraction was then sorted using a low magnification microscope (up to 40X).

Each wood charcoal sample was weight individually and then sieved to separate charcoal fragments by size. Two different mesh sizes were used (4mm and 2mm), resulting three size categories: over 4mm, between 4-2 mm and less than 2mm. Unfortunately, and unlike in the Mocha Island sites, each category size was not weight separately.

As part of my master's dissertation, an initial wood charcoal analysis of the site was done in 2018. This previous analysis only included samples of wood charcoal from the stratigraphic column of U1. As part of my PhD, in 2020 I analysed the excavation and flotation samples obtained from U2 and U1 that included some samples of the stratigraphic column (not included by mistake in the 2018 analysis). It was decided not to analyse the samples obtained from unit 3 because during the excavation the stratigraphic integrity of the test pit was questioned and later, the Thermoluminescence dates confirmed a disturbed context (also scarce samples were obtained from unit 3).

In terms of stratigraphy, sixteen sediment layers were recognized during the 2016 excavation (named L1 to L10, including sub-types). The description of each layer is summarized in table 16, and as it can be observed in figure 57, both excavation units do not show the same stratigraphical sequence. Some of the layers were recognized in U1 and U2 (top L1, L4, L5, and bottom layer L10). Although U1 reached until 2 meters deep, the archaeological deposit is not deeper than U2 because there are 30 cm of infilling at the beginning of the U1

sequence. Considering the stratigraphy and previous eight ^{14}C dates, only L5, L8.2, L8.3, L9.2, andL10 were previously dated. Similarly to Mocha Island, few vegetal taxon dates were obtained (n=2), in comparison to animal samples (n=4).

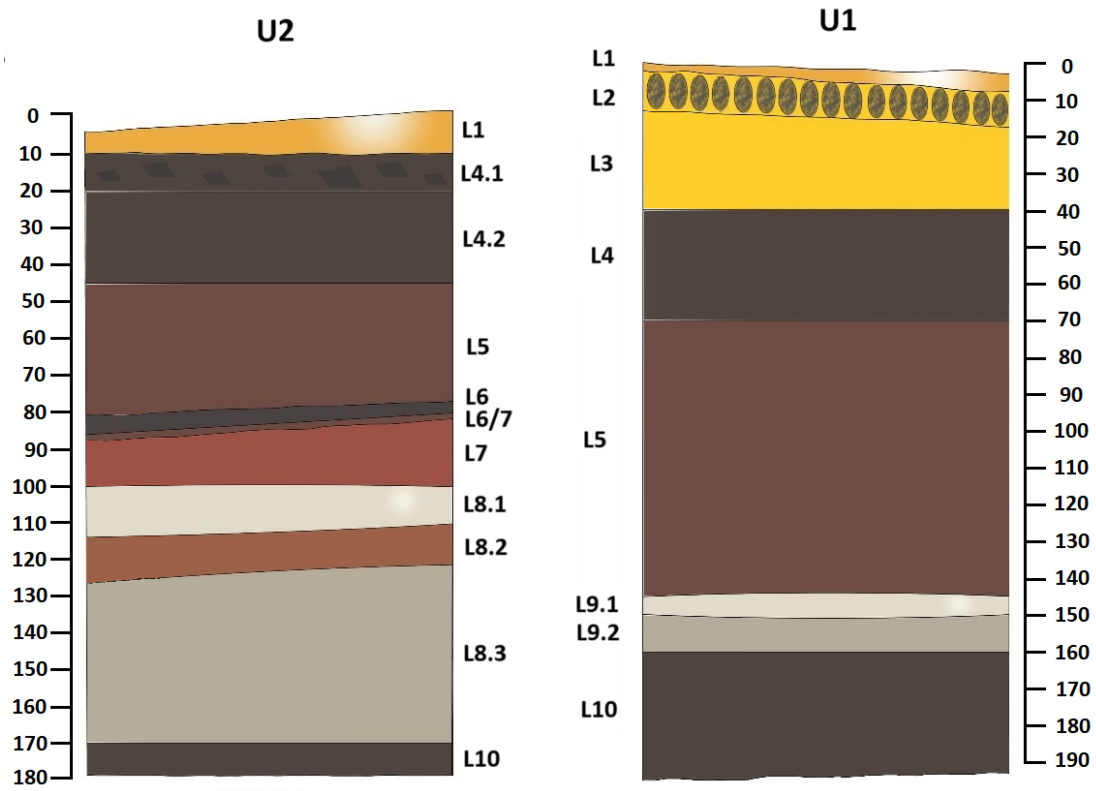


Figure 57: Stratigraphy of U2 and U1, modified from Roa 2018.

To improve the sequence of the site, fourteen vegetal samples were selected for dating (details in table 14, appendix A). The samples were selected giving priority to short lived specimens (seeds), and if they were not available, wood charcoal was then chosen (more often in the deeper layers).

Initially, six samples of *Cryptocarya alba* seeds were selected, two from U1 (L5: 90-100 cm and 130-140 cm), and four from U2 (L4:20-30, L8.2: 120-130 cm, L8.3: 130-140 cm and 160-170, but this last sample resulted in failure due to low yield). Three grains of *Triticum sp*. were selected from U1 (L4: 40 to 70 cm), and the laboratory sent a duplicate of the Triticum grain from the most superficial depth (40-50 cm). Three wood charcoal samples identified as D. wintery were also selected, one from U1 (L5) and two from U2 (L8.3: 160-170, L10: 170-180). Finally, a sample from wood charcoal identified as Myrtaceae type B was sent from U1 (L10: 190-200 cm). Although this last sample was not ideal in terms of taxonomic identification (identification at sub family level), it was important to obtain a date from the deepest layer in order to contrast it with earliest date of the site from a *Canis sp*. sample (526-627 cal. CE).

Table 16: Stratigraphy of U1 and U2, Cueva de los Catalanes

L1: Superficial layer of dung mixed with straw (less than 10 cm deep), identified in U1 and U2. Archaeological material: none.
L2 (U1, 10-20 cm): Pebble stone floor built around 20 years ago, apparently when the cave was used as corral. Archaeological material: none.
L3 (U1, 20-40 cm): Light brown filling presumable brought onto the cave to level and prepare the ground for the pebble stone floor (also used as mortar among the pebbles). Archaeological material: 1 stone flake.
L4 (U1, 40-70 cm; U2, 10- 45 cm): Dark brown soil matrix with high presence of rocks (from the collapse of the cave's roof or walls). Archaeological material: pottery fragments, post-Hispanic materials (metal), few stone flakes, several small bones (rodents), and non-charred some peach stones.
L5 (U1, 70 - 150 cm; U2 45-80 cm): Similar soil matrix than the previous layer, but slightly lighter (brown colour instead of dark brown), and with less rock inclusions. Archaeological materials: few in comparison to L4.
L6 (U2, 70-90 cm): Sandy matrix of grey colour. A feature of reddish soil was identified in the SE corner of the U2 (described as burned like soil). A flotation sample labelled as Rasgo 1/Feature 1 was bagged separately. Archaeological materials: high concentration (except for ceramic fragments)
L6/7 (U2, 80-90 cm): This layer is a transition between a compact matrix (clay and silt) intercalated with loose sand pockets. In certain areas is very thin (2 cm). Archaeological materials: Abundant wood charcoal and animal bones (mainly rodents), and few ceramic fragments (n=4).

Table 16 (continuation): Stratigraphy of U1 and U2, Cueva de los Catalanes

L7 (U2 80-100 cm): Non-homogenous layer that shows two types of matrixes: a light brown clayey one and a grey clay-silty one.
L8 (U2 100-120 cm): Layer of whitish-grey colour that could represent a mixture of ashes, charcoal and possible remains of a volcanic episode. Archaeological materials: few.
L8.2 (U2, 110-130 cm): Similarly to L7, non-homogenous layer that shows a mixture of clay-sandy and clay-silty sediments. Dark spots of concentrated charcoal were also registered. A flotation sample was taken from an area were 3 charred *Cryptocarya alba* seeds were found.
L8.3 (U2,120-170 cm): Non-homogenous layer, presents the same sediments from L8.2 (clay-sandy and clay-silty), but with frequent inclusions of ash-silty pockets (whitish colour). Archaeological material: abundant.
L9 (U1, 150-165 cm): Layer composed mainly of ash like sediments (resembles L8.1 from U2, but they were registered as different layers). During the excavation, L9 was subdivided into two: L9.1 (50 - 158 cm, grey layer of ash like sediments), L9.2 (registered underneath L9.1:158-165 cm, apparently its darker colour indicates a mixed of the ash like sediment with some soil from the layer below (L10).
L10 (U1, 160- 200 cm; U2, 170-180): Dark and fine sand that seems come from the degradation of the cave's stone. Underneath the sand, a continuous rock base was exposed, suggesting no undelaying deposits.

8.3 AMS dating results: Cueva de los Catalanes Chronology

All the previous eight ^{14}C dates of the site were calibrated incorporating the new fourteen AMS dates (figure 58, details of the dates are provided in table 14, appendix A). Just as it was also done in the sites of Mocha Island, the calibration was done in OxCal 4.4 using the SHCal20 calibration curve (Hogg *et al*. 2020). A total of 22 dates indicates that the cave occupation starts around the 550 cal. CE, during the Early Ceramic Period, then continuous into the Late Ceramic Period (Post 1000 CE) and Early Historic Period (Post 1550 CE).

Considering the stratigraphy and dates, it is possible to differentiate three main occupation phases. The first one includes eleven ^{14}C dates covering from the 526 to the 1180 cal. CE. In U1, this phase is represented by four dates from L10 and L9 (150 -200 cm), indicating a temporal range between the 600 and 835 cal. CE. As it can be observed in figure 59, the dates sequence from U1 seems to show little stratigraphical disruption (older dates at the bottom of sequence). In U2, the picture is different (figure 60), because the dates from this first phase are not in stratigraphical order. The seven dates from U2 were obtained from L8.2, L8.3 and L10, and they indicate a temporal range from 526 to 1180 cal. CE. Paired dates taken at the same depth, as well as the layer descriptions from the fieldnotes indicate a disturbed context. Since some human remains were identified in the L8.3 dating to 1040-1153 cal. CE, one of the possibilities is that the stratigraphical disturbance of these layer was due to

an inhumation event or occupation of the post-1000 CE Period. However, no distinct burial context was identified.

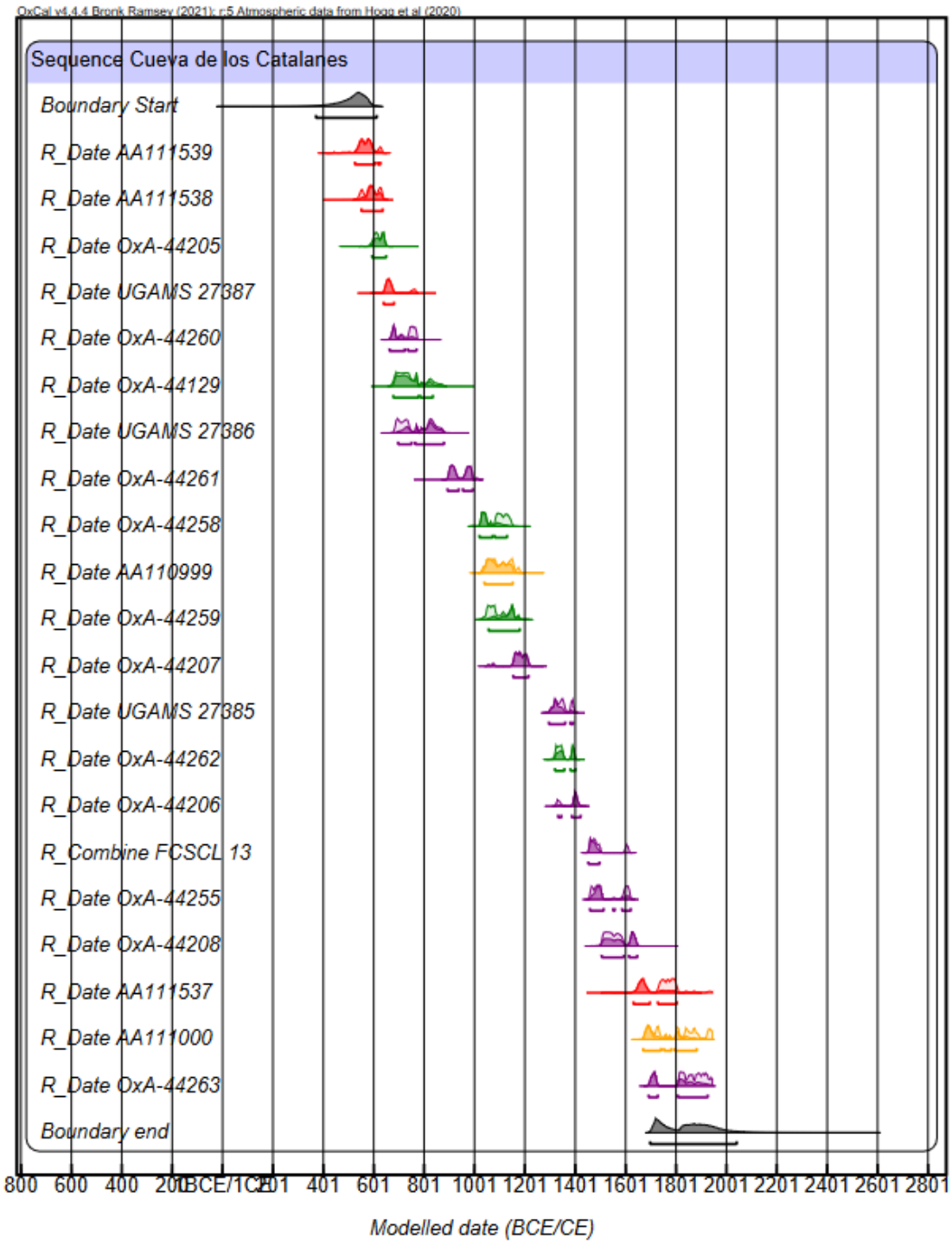


Figure 58: ^{14}C dates of Cueva de los Catalanes. Colours indicate sampled material: red= animal bones, green= wood charcoal, yellow= human bones, purple= seeds/crops.

After this first phase, four dates indicate a phase between the 1155 to 1422 CE. In U1, three dates were obtained from L5 (90-140 cm), and in U2 one date was sampled from Layer 7 (90-100 cm).

The last phase corresponds to the post-Hispanic Contact period (after 1550 CE). Seven dates indicate a temporal range from around 1550 to the 19th century. In U1, four dates were obtained from three *Triticum sp*. samples and they all correspond to the 16th century, resulting in the earliest taxon dates for *Triticum* in Southern Chile. In U2, the three dates between the 17th and 19th centuries, although some of these dates have wide ranges that extended beyond the 19th century.

The dates and stratigraphy indicate that there is more disturbance in the sequence from U2 than in U1. For the first phase, U1 shows a narrower chronological range (526-627 to 679-835 cal. CE) than U2 (640-681 to 1057-1180 cal. CE), but more dates were obtained from U2 (n=7) than from U1 (n=4) for this phase. This phase corresponds to the ECP (although is possible that in U2 there might be a LCP component by the end of the ECP sequence).

In comparison, the LCP is the Phase with less ^{14}C dates (only four). While in U1 the entire L5 can be ascribed to the LCP, in U2 L5 shows post-contact dates, so only L6 and L7 were ascribed to the LCP. Then, the Post-contact Phase corresponds to L4 in U1, and L4, L5 in U2.

The latest 14 ^{14}C dates improved significantly the chronology of the site and helped to understand in a better way the stratigraphy. Just based in the current

radiocarbon evidence, it is possible to propose that the cave was used recurrently during the ECP, but then, during the LCP the cave was used less frequently. This could correlate to the changes in residential mobility observed during the LCP that suggest a more sedentary residential pattern after the 1000 CE, in contrast to the logistical mobility characteristic of the ECP (Adán *et al.* 2016). From another line of evidence, the frequency of rodent remains suggests a more sporadic use of the cave between the 0-130 cm depth, which in broad terms covers the LCP and post-contact Periods (Zúñiga 2021).

In relation to the post-contact period, the obtention of direct taxon dates is an achievement on its own. From Historical documents it was known that wheat was introduced and adopted early on by the indigenous populations, but there is still little direct archaeological evidence about the process.

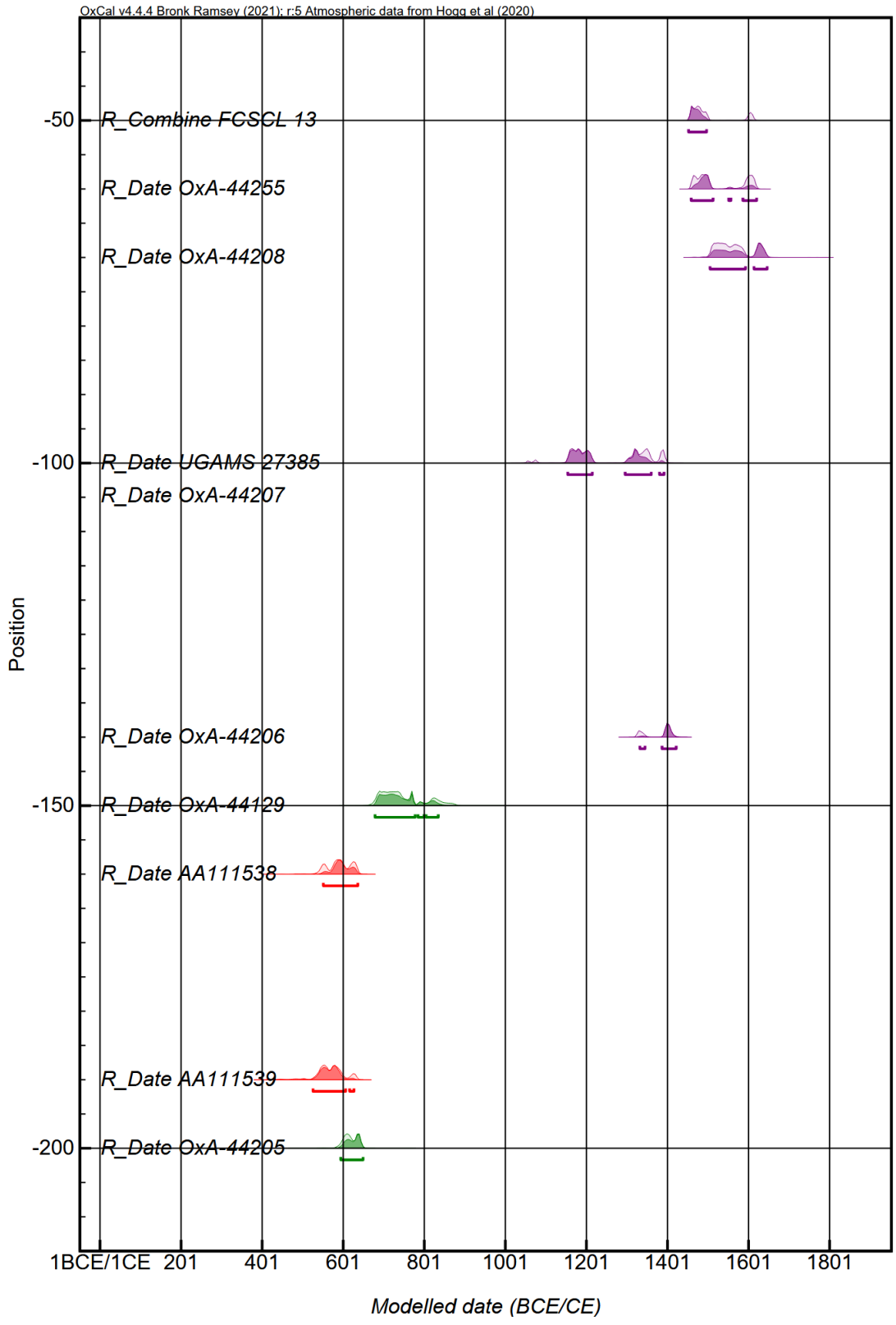


Figure 59: ^{14}C dates in relation to depth in U1. Colours indicate sampled material: red= animal bones; green= wood charcoal; purple= seeds/crops.

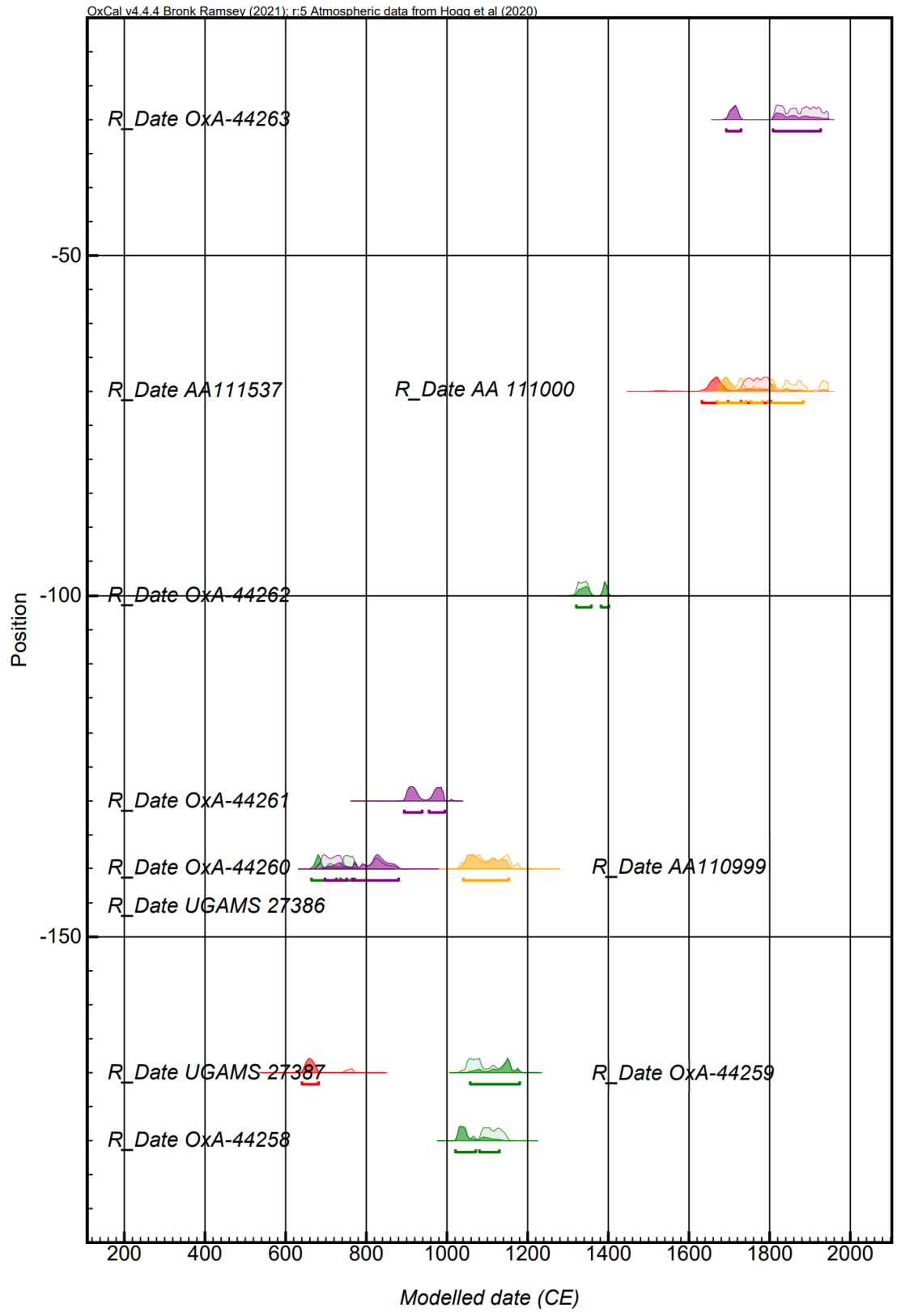


Figure 60: ^{14}C dates in relation to depth in U2. Colours indicate sampled material: red= animal bones; green= wood charcoal; yellow= human bones, and purple= seeds/crops.

8.4 Wood charcoal analysis results

A sum of eleven flotation samples (U1=7, U2=4), and 31 wood charcoal samples from the excavation were analysed (U1=6, U2=25). Considering the weight of the samples, most of the analysed wood charcoal correspond to handpicked samples recovered during the excavation (144.68 gr versus 40.02 gr recovered through flotation, see details in table 15, appendix A). In comparison (and including the samples analysed in 2018), more wood charcoal was recovered in U2 than in U1 (figure 61). Nevertheless, they are not directly comparable, since different sampling strategies were used in each unit. While in U1 most of the samples were obtained from a flotation column, in U2 most of the were collected during the excavation and no systematic flotation samples were obtained.

Because the samples were not weight separately by different size category, a priori is not possible evaluate if there are layers showing more fragmentation than others. The layer showing more recovered fragments in U1 is Layer 5 (80-100 cm), and in U2 they are Layer 8.2 (120-130 cm) and Layer 8.3 (120-160 cm).

A total of 1550 carbonized remains were analysed, and among them two were categorized as unidentified vegetal tissue that is not considered in the final count. Of the sum of 1548 wood charcoal fragments, 51.8% was identified (n=802), 11.3 was classified as unknown angiosperm wood charcoal (n=175) and a 36.9 as non-identifiable (n=571).

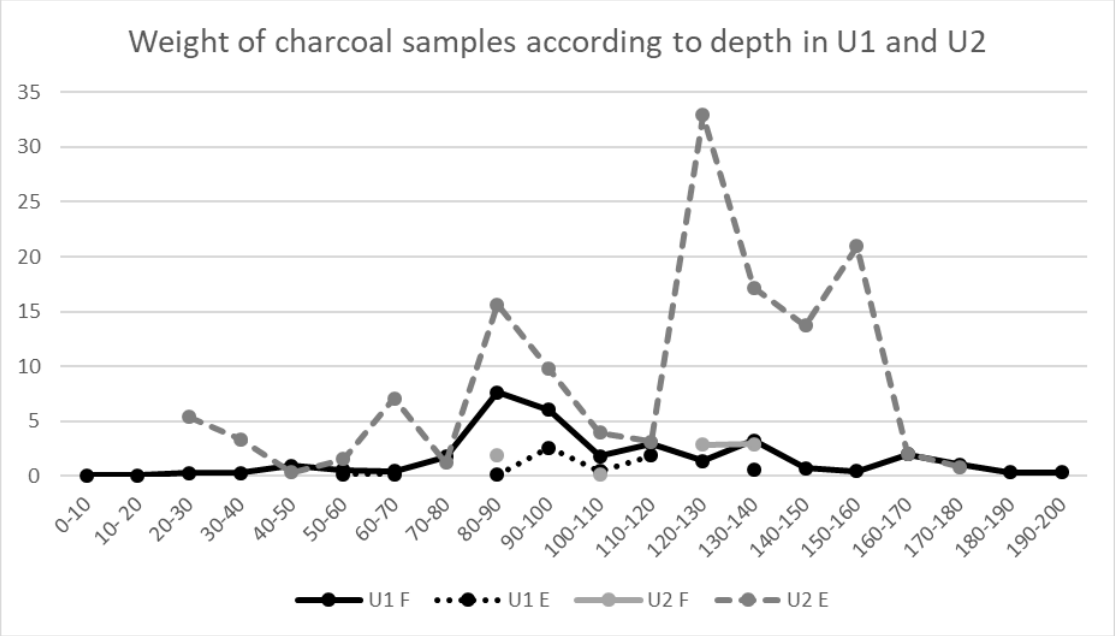


Figure 61: Weight of flotation and excavation samples from U1 and U2.

In U1, the analysed samples show a small sample size (less than 100 fragments per the 10 cm levels, figure 62). Because of this, the results obtained will be presented together with the results from 2018 in order so overcome the small sample issue and propose interpretations based on a stronger data set.

In U2 there is also variation among the samples, but the identified category seems to be the predominant one in all of them (figure 63). In order to present the results in an understandable way, U1 and U2 will be described separately, to then compare them and integrate the other archaeobotanical information of the site.

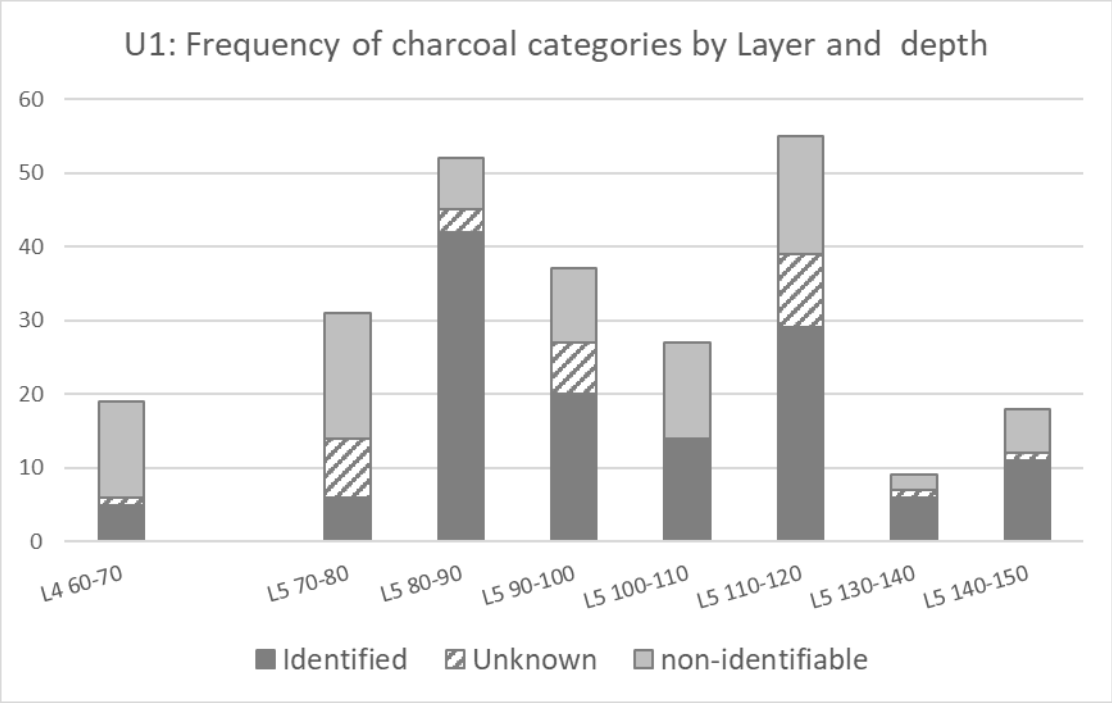


Figure 62: frequency of charcoal categories in U1.

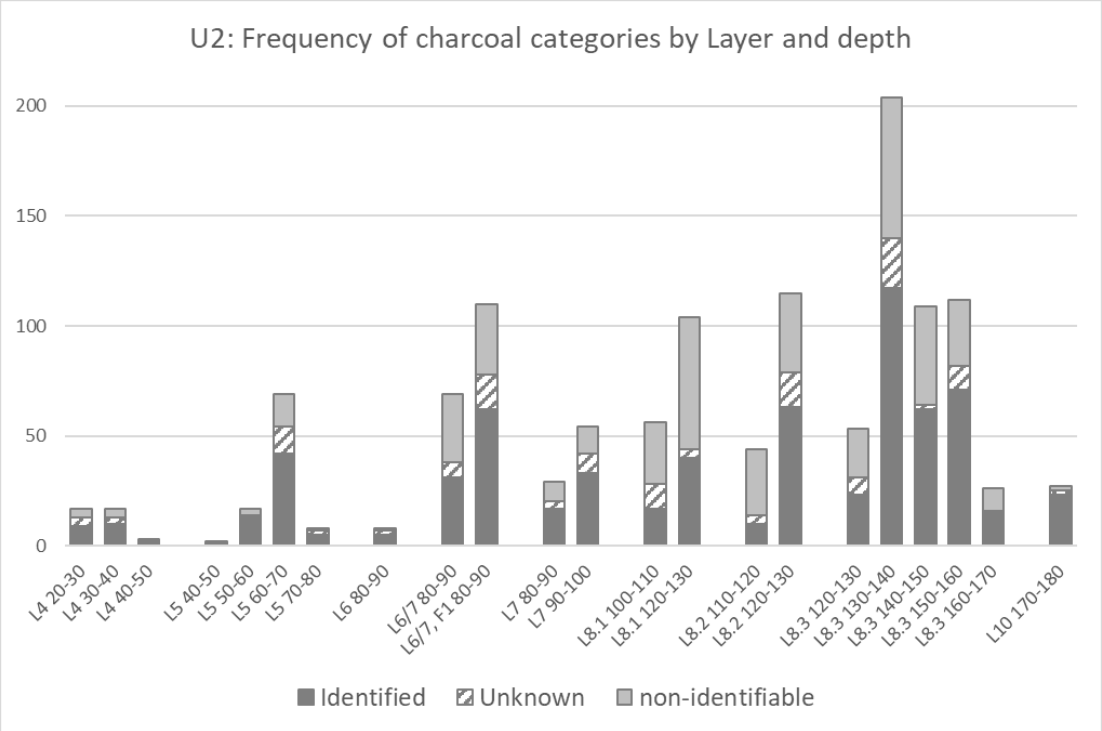


Figure 63: frequency of charcoal categories in U2.

8.4.1 U1 Cueva de los Catalanes

The analysis of U1 considers 20 flotation samples and seven excavation samples. In sum, 1387 wood charcoal fragments were analysed (2020= 297, 2018= 1090, plus 3 bark fragments). A 52.7% of the assemblage was taxonomically identified (n=731), an 8.2% was categorized as an unknown angiosperm (n=114), and 39.1% was determined as non-identifiable.

Only considering the flotation samples (figure 64), is possible to observe variation in the percentage of each identification category. The highest identification percentages are found in L5 (around 65%) between the 80-100 cm (same depth where a peak of charcoal was observed), and the lower ones are register in L10 (20% to 30% between the 180-200 cm). These percentages need to be considered cautiously because while L5 shows a high concentration of wood charcoal, the deeper levels of L10 have a small sample size (n=14 between the 180-200 cm).

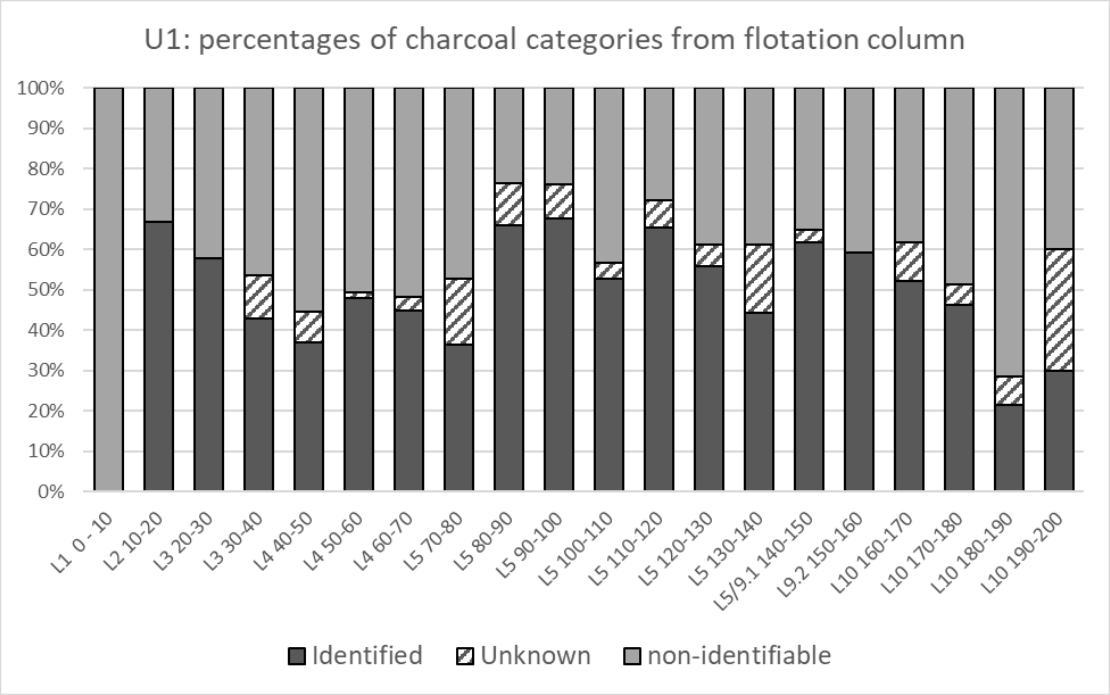


Figure 64. relative frequency of charcoal categories from flotation column in U1.

8.4.1.1 Identified taxa

A total of 20 angiosperm taxa were recognized, including one monocotyledon taxon (Identified to class level as Liliopsida). Among the remaining 19 dicot taxa, two were identified to family level, two to subfamily level, seven to genus level and eight to species level. Altogether, the identified taxa of U1 represents 15 families of native woody taxa (table 17).

The highest taxa richness is observed in L5 (n=20, figure 65), same layer that show the highest diversity indexes (figure 66). The sample with the highest number of identified taxa (n=19), correspond to the one taken between 90-100

cm, but the sample with highest diversity Index is the one taken between the 70-80 cm (H=3.5).

Table 17: U1 identified taxa.

Class	Family	Genus/species	N	%	U
Liliopsida (Monocots)			17	2.3	29.6
Magnoliopsida (Dicots)	Aextoxicaceae	*A. punctatum*	6	0.8	18.5
	Anacardiaceae	*Lithrea caustica*	21	2.9	29.6
		Schinus sp.	39	5.3	40.7
	Berberidaceae	*Berberis* sp.	6	0.8	14.8
	Celastraceae	*Maytenus* sp.	29	3.9	18.5
	Cunoniaceae		23	3.1	22.2
	Elaeocarpaceae	*Aristotelia chilensis*	7	0.9	14.8
	Fabaceae		55	7.5	37.0
	Lauraceae	*Cryptocarya alba*	26	3.6	33.3
		Persea lingue	41	5.6	51.8
	Monimiaceae	*Laurelia/Laureliopsis*	14	1.9	22.2
		Peumus boldus	40	5.5	44.4
	Myrtaceae	Type A	176	24.1	66.7
		Type B	31	4.2	37.0
	Nothofagaceae	*Nothofagus* sp.	80	10.9	55.5
	Quillajaceae	*Quillaja saponaria*	17	2.3	25.9
	Salicaceae	*Salix sp.*	9	1.2	22.2
	Scrophulariaceae	*Buddleja* sp.	1	0.1	3.7
	Winteraceae	*Drimys winteri*	93	12.7	55.5
Total			731	100	-

The most frequent identified taxon is Myrtaceae type A. Almost a quarter of all the identified fragments correspond to this taxon (24.1%), followed by *Drimys wintery* (12.7%) and *Nothofagus sp*. (10.9%). These three taxa also show the highest ubiquity (figure 67). Other tree taxa with high frequency and high ubiquity are *Persea lingue*, *Peumus boldus, and Schinus* sp.

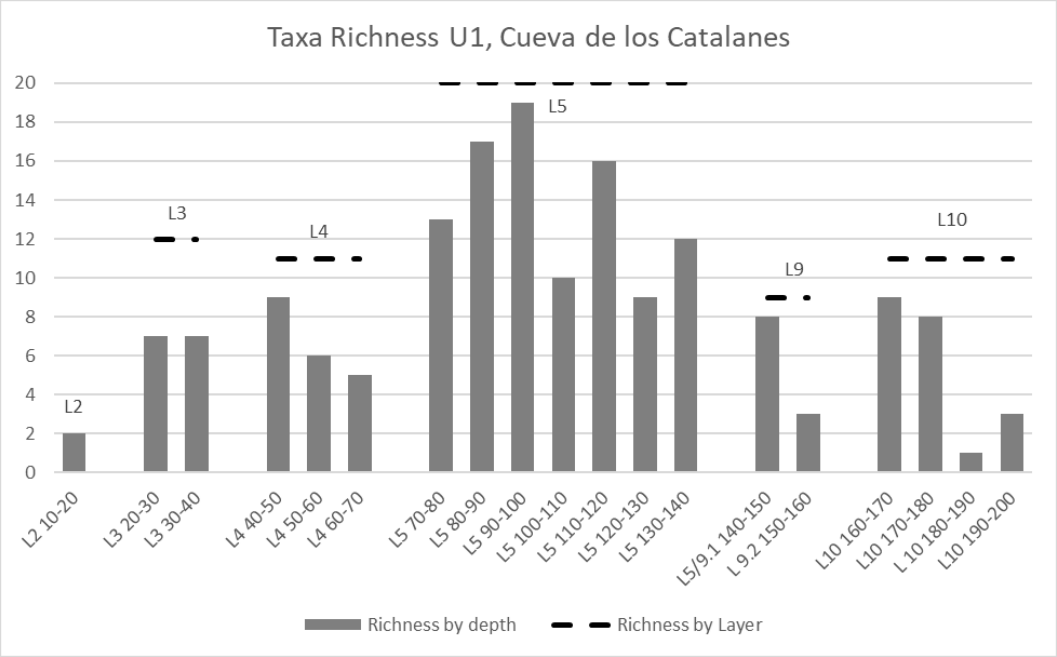


Figure 65: taxa richness in U1, according to layer and sample.

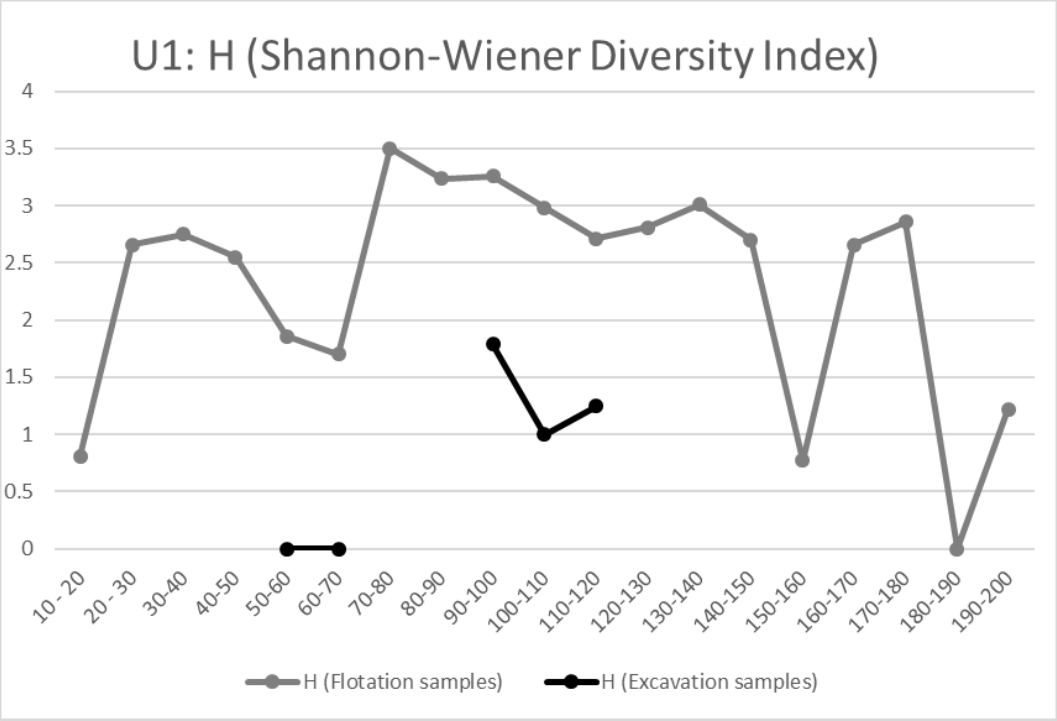


Figure 66: U1 sample's diversity index.

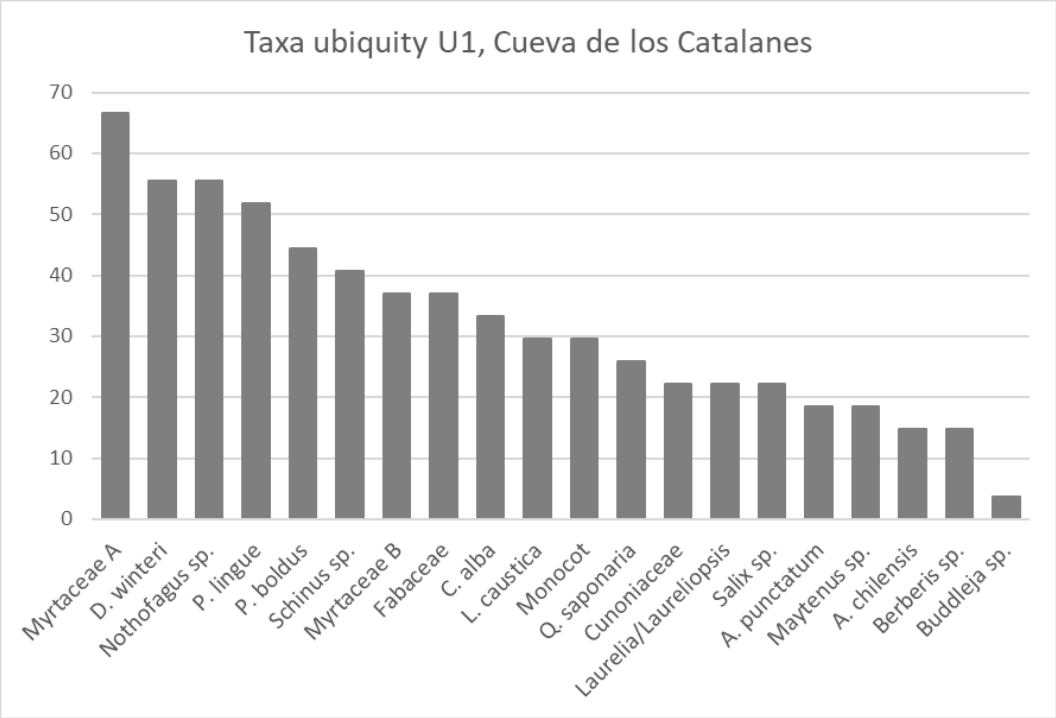


Figure 67: U1 taxa ubiquity.

In terms of relative frequency and only considering the flotation samples (figure 68), there is variation of taxa representation along the sequence. In the deepest samples (L10, 160-200 cm) the predominant taxa are Myrtaceae type B, Myrtaceae type A, *Persea lingue* and *Shinus sp*. Then, in L9 (150-160 cm) *Nothofagus sp.* predominates in the assemblage. In L5 the predominant taxa are Myrtaceae Type A, *Nothofagus sp., D. winteri* and Fabaceae. *Nothofagus sp.* seems to be more represented in the deeper samples of L5 (120-150 cm), while *D. wintery* does it in the middle section of the layer (100-120 cm) and Myrtaceae type A is more important top section of L5 (80-100 cm). In L4 Myrtaceae type A is the most frequent identified taxa, while in L2 and L3 *Nothofagus sp.* is the predominant taxon.

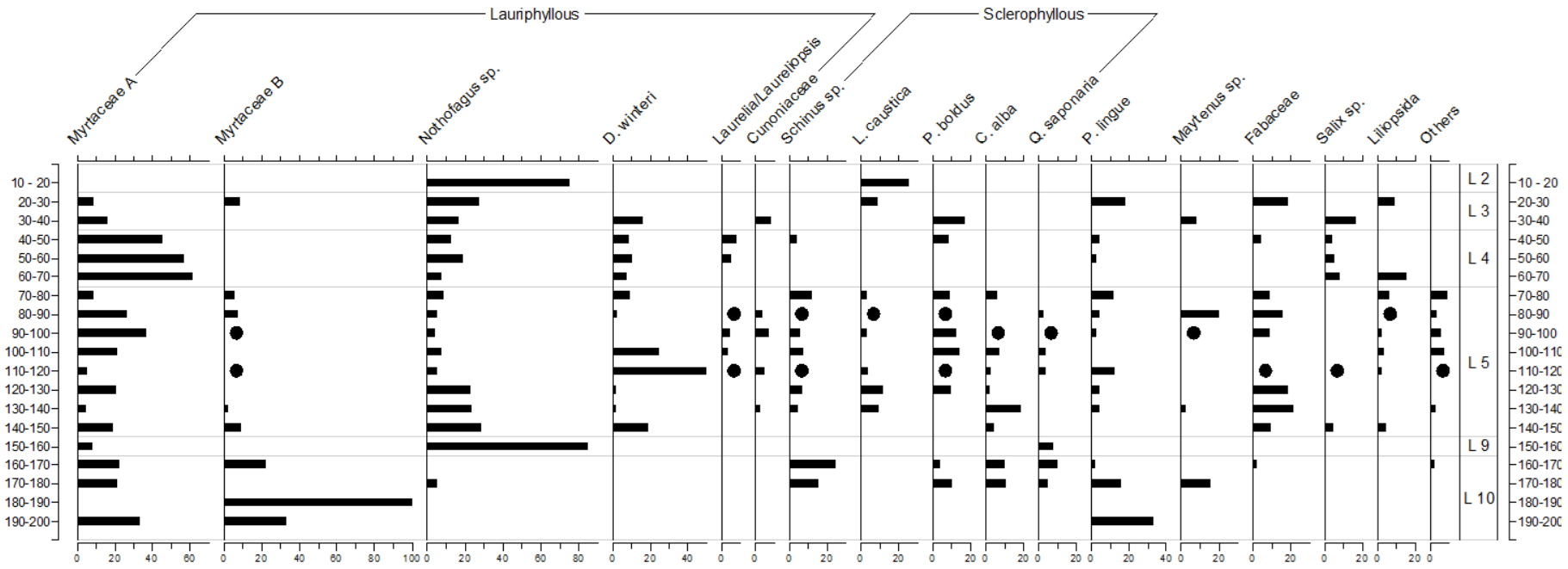


Figure 68: Relative frequency of identified taxa from U1 flotation column. Circles represent values under 2%.

The majority of the identified taxa were registered in most of the layers. *Drimys winteri* is the only frequently identified taxon absent from the samples beyond the 150 cm. The other taxa showing a similar distribution are Cunoniaceae, *Lithrea caustica*, Liliopsida and *Salix sp*., but they were less frequently identified along the sequence as well.

8.4.1.2 Unknown taxa

Among the 114 indeterminate angiosperm fragments, there were two types observed in different samples (descriptions of taxa are provided in appendix B). One of them was also recognized in the samples from P5 of Mocha Island, and it was categorized as unknown type A. The other type was categorized as unknown type D, and while type A was concentrated in one sample, type D was recognized in three different samples (table 18).

Table 18: frequency of unknown types in U1.

Unknown Fragments	Layer 5		Layer 10	Total
	70-80 cm	90-100 cm	180-190	
Type A		4		4
Type D	1	1	1	3

8.4.1.3 Non-identifiable taxa

Among the 542 fragments categorized as non-identifiable, an 82.8% correspond to small size fragments (between 4 and 2 mm). Almost 50% of the

non-identifiable fragments were categorized as such because it was not possible to observe properly the tree anatomical plains (mainly due to small fragment size or irregular shape). There are many fragments presenting more than one type of alteration (shown separately in and in table 19), but the values in this written section represent the sum of each alteration

Almost a third of all the non-identifiable fragments show one or more taphonomic features (34.8%). The alterations of wood growth were registered mainly as knots (9.2%), and other anatomical issues such as small diameter/gauge were observed in a similar percentage (8.7%).

Table 19: Detail of non-identifiable fragments in U1

Non-identifiable fragments	**Over 4 mm**		**4-2 mm**		**Total**	
	N	**%**	**N**	**%**	**N**	**%**
Presence of one or more taphonomic features	34	6.3	141	26.0	**175**	**32.3**
Alterations related to wood growth	16	2.9	23	4.2	**38**	**7.0**
Small wood gauge (twigs)	9	1.7	35	6.4	**44**	**8.1**
Presence of alterations related to wood growth and one or more taphonomic features	4	0.7	7	1.3	**12**	**2.2**
Small wood gauge with presence of one or more taphonomic features	1	0.2	2	0.4	**3**	**0.5**
Not possible to observe all anatomical sections	29	5.3	241	44.4	**270**	**49.8**
Total	**93**	**17.2**	**449**	**82.8**	**542**	**100**

8.4.1.4 Alterations in the wood anatomy of the assemblage

In the entire sequence of U1, 54 fragments showed anatomical alterations registered as knots. They were mainly identified in fragments over 4 mm

(57.4%), and the rest correspond to fragments between 4 and 2 mm (42.6%). Most of the fragments showing knots were categorized as non-identifiable (92.6%), and only two identified taxa showed knots in small frequencies (table 20).

Table 20: wood charcoal from U1 showing anatomical alterations.

Category		**Over 4 mm**		**4-2 mm**	
		N	**%**	**N**	**%**
Identified	Myrtaceae	1	1.8		
	Drimys winteri			1	1,8
Unknown		2	3.7		
Non-identifiable		20	37.0	30	55.5
Total		**23**	**42.6**	**31**	**57.4**

8.4.1.5 Diameter measurements of the assemblage

Diameter estimations could not be conducted due to the fragmentation of the wood charcoal samples. Nevertheless, in 45 fragments it was possible to observe a complete diameter (less than 2 cm), indicating the preservation small gauge twigs in Layer 5, 9 and 10. Most of the assemblage was categorize as non-identifiable and only two fragments were identified taxonomically as *Drimys wintery*.

8.4.1.6 Taphonomy of the assemblage

A total of 311 fragments showed at least one taphonomic feature, representing a 22.4% of the analysed wood charcoal fragments of U1. If considered separately (figure 69), the most frequent features registered was vitrification (n=175, 12.6% of the U1 wood charcoal total), and in second place hyphae

(n=71, 5.1%). But if considered as category, the indicators related to the combustion process (V: vitrification, C: radial cracks in figure 69), are the predominant taphonomic feature in the assemblage (14.3%). The presence of structural collapse and infillings were also registered in less proportion (SC=Structural collapse and I=infillings, figure 69) and indicators of xylophage insects were absent.

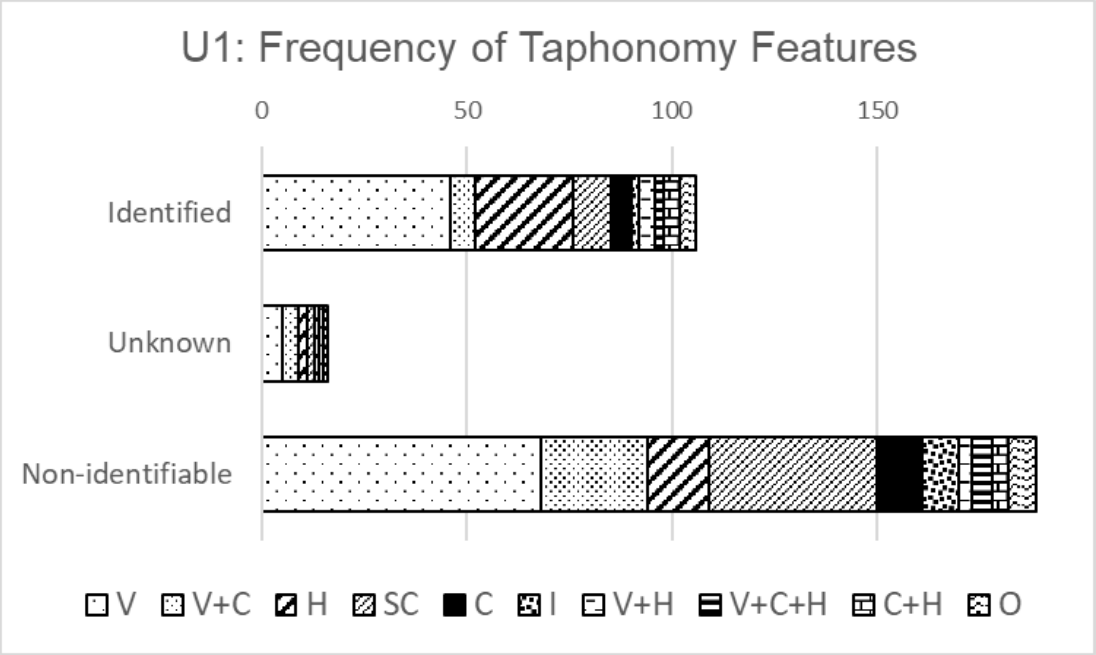


Figure 69: U1 frequency of taphonomic features (V: vitrification, C: radial cracks, SC: structural collapse, H: hyphae, I: infillings, and O: others)

Among the identified fragments, a 14.5% showed at least one taphonomic feature, while in the unknown category it reached just 1.4%. In terms of layers and depth (figure 70), if discarding the small size samples with small size (L1, L2, L5 80-100, and L10 180-200), the highest prevalence of taphonomic

features is in Layer 10 (around 50%). Layer 5 shows percentages between 10% and 30%, and Layer 4 under 20%.

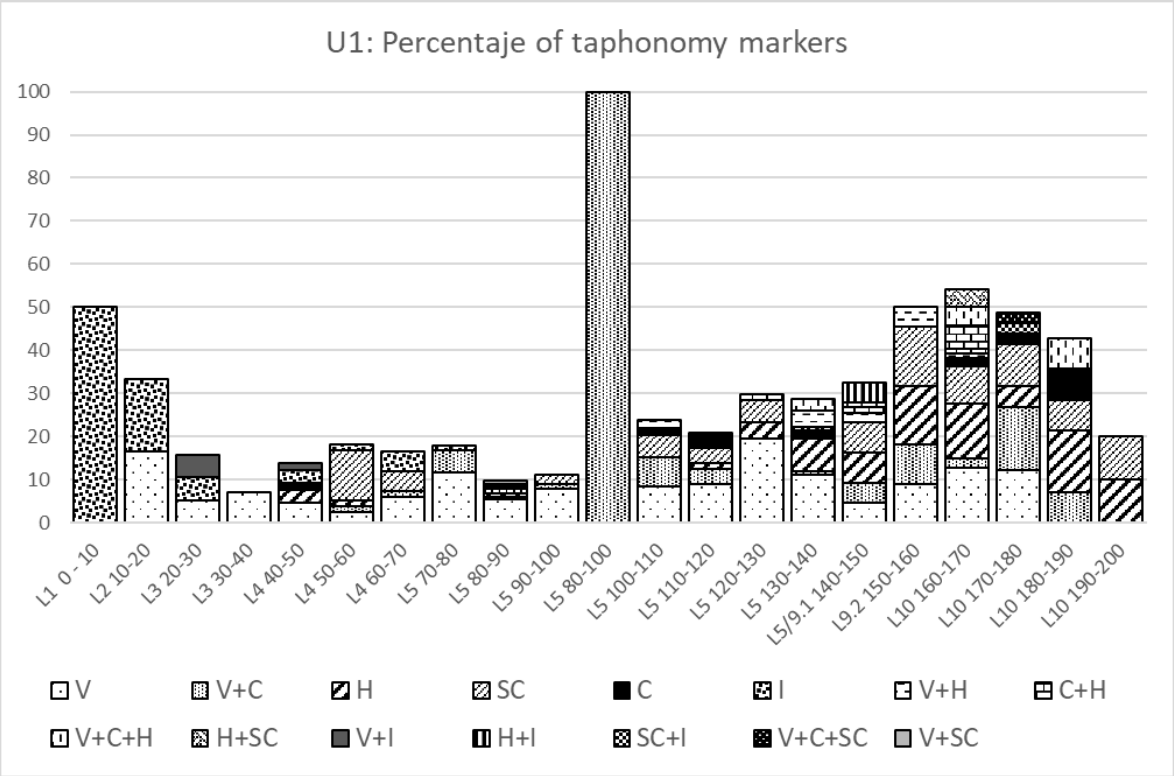


Figure 70: relative frequency of taphonomic features in U1 according to sample (V: vitrification, C: radial cracks, SC: structural collapse, H: hyphae, and I: infillings).

Since a significant part of the fragments showed more than one taphonomic features simultaneously (n=71), the more frequent features are presented separately (vitrification, hyphae and radial cracks), while the remaining ones were grouped together.

Vitrification was registered mainly on its own (n=119, 8.6% of U1), and in less proportion along with radial cracks, hyphae, and infillings (figure 71, details in table 16, appendix A). Among the identified fragments, the most frequent taxa

showing vitrification are the ones with a high frequency in the site´s wood charcoal assemblage like Myrtaceae type A and *Nothofagus sp.* Some of the other identified taxa showing vitrification belong to the Lauraceae (*C. alba,* and *P. lingue*) and Anacadiaceae (*Schinus* sp., and *L. caustica*) families.

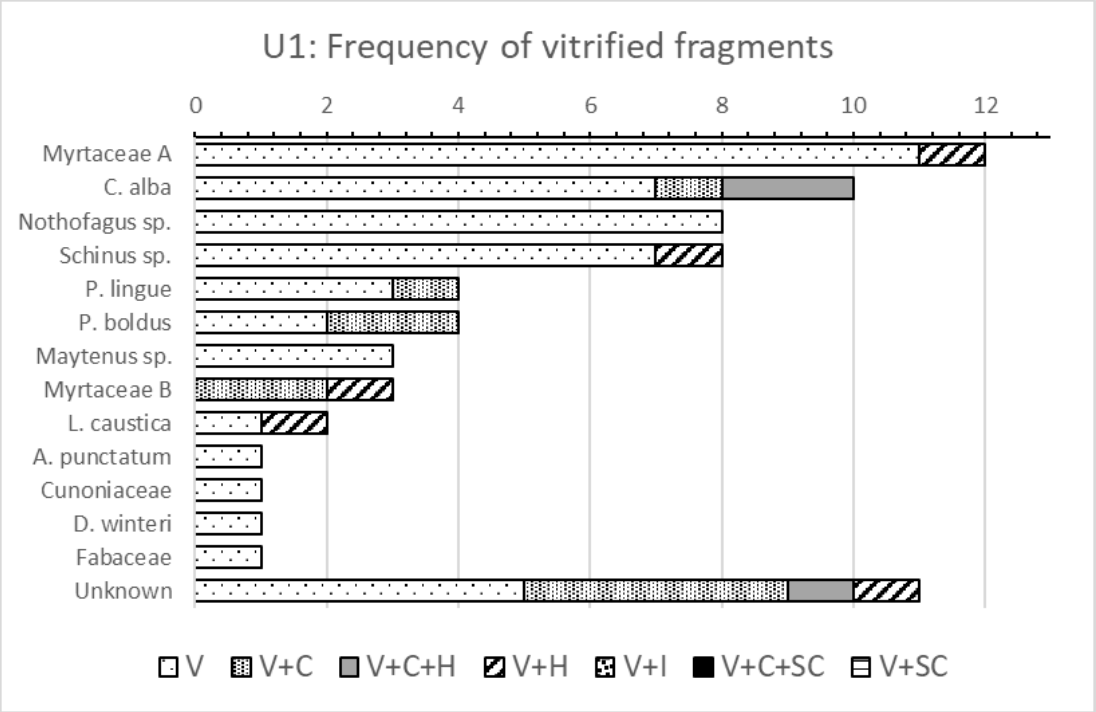


Figure 71: detail of vitrified fragments in U1 (V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse).

Hyphae were identified as a biological marker of wood decay in 71 fragments. Hyphae were identified mainly on its own (2.9% of the site's wood charcoal total), but also along taphonomic features related to the combustion process (vitrification and radial cracks). Among the identified taxa, only eleven taxa presented biological markers of wood decay (figure 72), being the Myrtaceae types A and B, and *Nothofagus sp*. the most frequent.

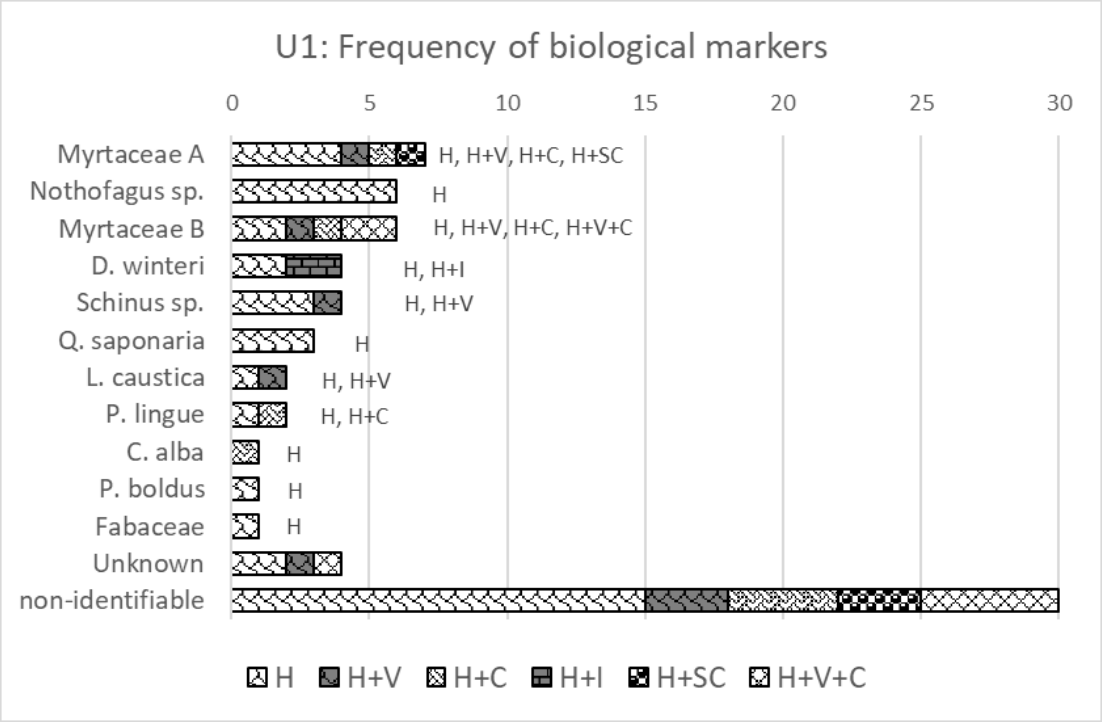


Figure 72: U1 fragments with biological markers (H: hyphae, V: vitrification, C: radial cracks, SC: structural collapse).

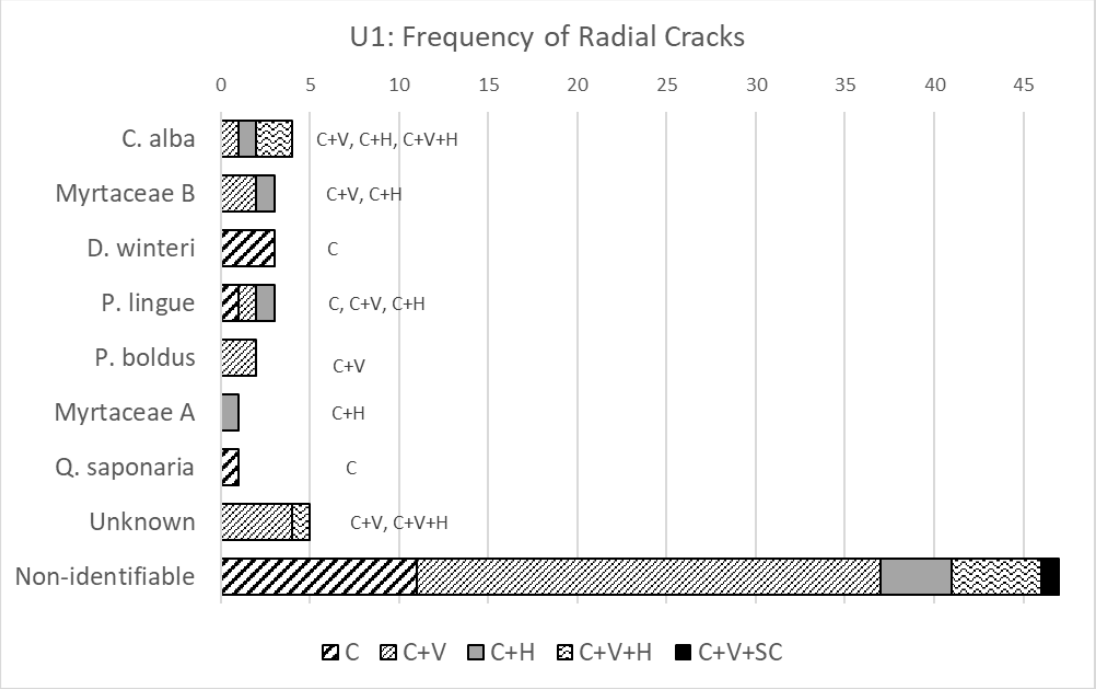


Figure 73: U1 fragments with radial cracks (C: radial cracks, V: vitrification, H: hyphae, I: infillings, SC: structural collapse).

Most of the fragments showing radial cracks also showed vitrification (figure 73, see details in table 16, appendix B). There are few identified fragments showing radial cracks (n=17), and they correspond to seven different taxa. Except for *D. winteri* and *P. boldus,* most of the identified taxa do not present wide cell rays (but they are at least 3 cells wide).

Structural collapse was registered in 46 fragments, most of them categorized as non-identifiable (details in table 16, appendix A). Six identified taxa show structural collapse in low frequencies (Myrtaceae A = 5, *L. caustic*a = 2, *D. winte*ry = 1, *Aristotelia chilensis* = 1, *Nothofagus* sp. = 1, *P. boldus* = 1). Infillings were only recognized in 19 fragments, corresponding five of them to identified taxa (*D. winteri*= 3, Fabaceae =1, and *P. boldus* =1). Structural collapse and infillings were recognized simultaneously only in one fragment identified *as P*. boldus.

8.4.2 U2 Cueva de los Catalanes

The analysis of U2 comprised 25 excavation samples and 4 flotation samples (details in table 15, appendix A). In sum, 1253 wood charcoal fragments were analysed. A 53.6% of the assemblage was taxonomically identified (n=672), an 11.3% was categorized as unknown angiosperm (n=141), and 35.1% was determined as non-identifiable.

By considering the Layer of each sample (figure 74), is possible to observe variation in the percentage of each identification category. L10 is the only layer with over 80% of identified fragments, but it also has a small sample size (n=27). In L8.1, L8.2 and L8.3 show the highest percentages of non-identifiable fragments (33.9% to 55%), and these three layers also concentrate 63% of the fragments from U2.

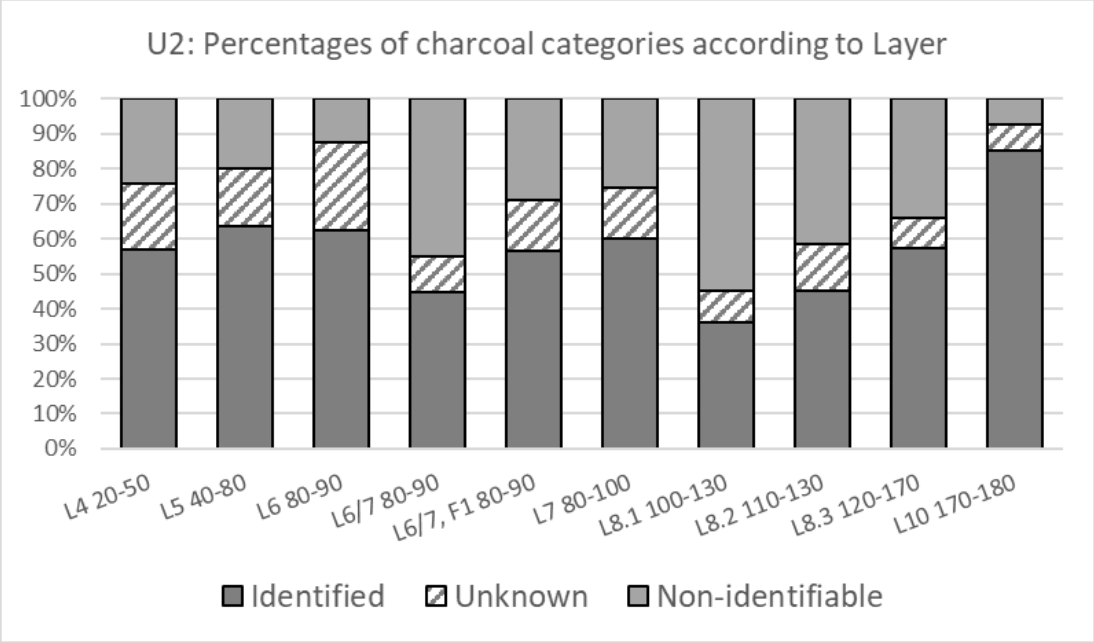


Figure 74: Relative frequency of charcoal identification categories in U2 according to layer.

8.4.2.1 Identified taxa

A total of 24 angiosperm taxa were recognized, including two monocotyledon taxa. Most of the monocots were identified to class level as Liliopsida, and only one fragment was identified to genus level as *Chusquea sp*. Among the remaining 22 dicot taxa, three were identified to family level, two to subfamily level, ten to genus level and seven to species level. Altogether, the identified taxa of U2 represents 19 families of native woody taxa (table 21, N: absolute frequency, %: percentage in relation to total number of identified fragments, U: ubiquity).

Table 21: U2 identified taxa.

Class	**Family**	**Genus/species**	**N**	**%**	**U**
Liliopsida (Monocots)			17	2.5	13.3
	Poaceae	*Chusquea* sp.	1	0.1	3.3
Magnoliopsida (Dicots)	Aextoxicaceae	*Aextoxicon punctatum*	2	0.3	3.3
	Anacardiaceae	*Lithrea caustica*	18	2.7	30.0
		Schinus sp.	76	11.3	53.3
	Berberidaceae	*Berberis* sp.	9	1.3	16.7
	Celastraceae	*Maytenus* sp.	56	8.3	60.0
	Cunoniaceae		57	8.5	63.3
	Elaeocarpaceae	*Aristotelia chilensis*	4	0.6	33.3
	Escalloniaceae	*Escallonia* sp.	1	0.1	2.3
	Fabaceae		53	7.9	33.3
	Grossulariaceae	*Ribes* sp.	4	0.6	6.7
	Lauraceae	*Cryptocarya alba*	22	3.3	30.0
		Persea lingue	7	1.0	20.0
	Monimiaceae	*Laurelia/Laureliopsis*	2	0.3	3.3
		Peumus boldus	67	10.0	40.0
	Myrtaceae	Type A	96	14.3	56.7
		Type B	3	0.4	10.0
	Nothofagaceae	*Nothofagus* sp.	66	9.8	60.0
	Proteaceae		3	0.4	10.0
	Quillajaceae	*Quillaja saponaria*	3	0.4	20.0
	Salicaceae	*Salix* sp.	5	0.7	13.3
	Scrophulariaceae	*Buddleja* sp.	15	2.2	23.3
	Winteraceae	*Drimys winteri*	85	12.6	40.0
Total			672	100	-

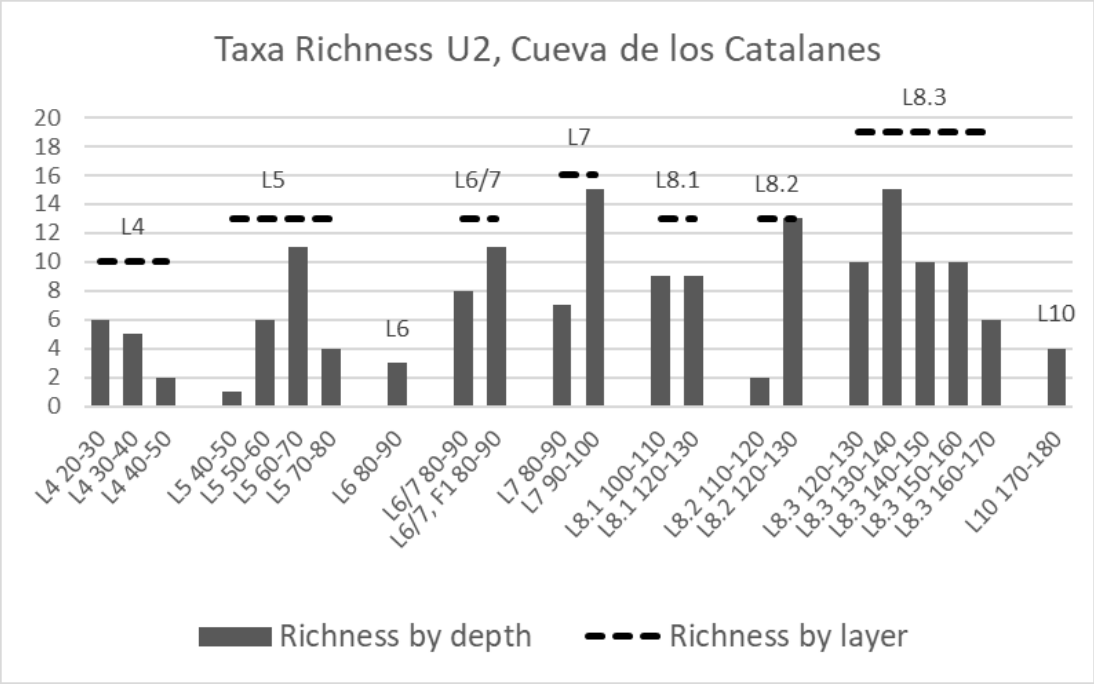


Figure 75: taxa richness in U2 according to layer and sample.

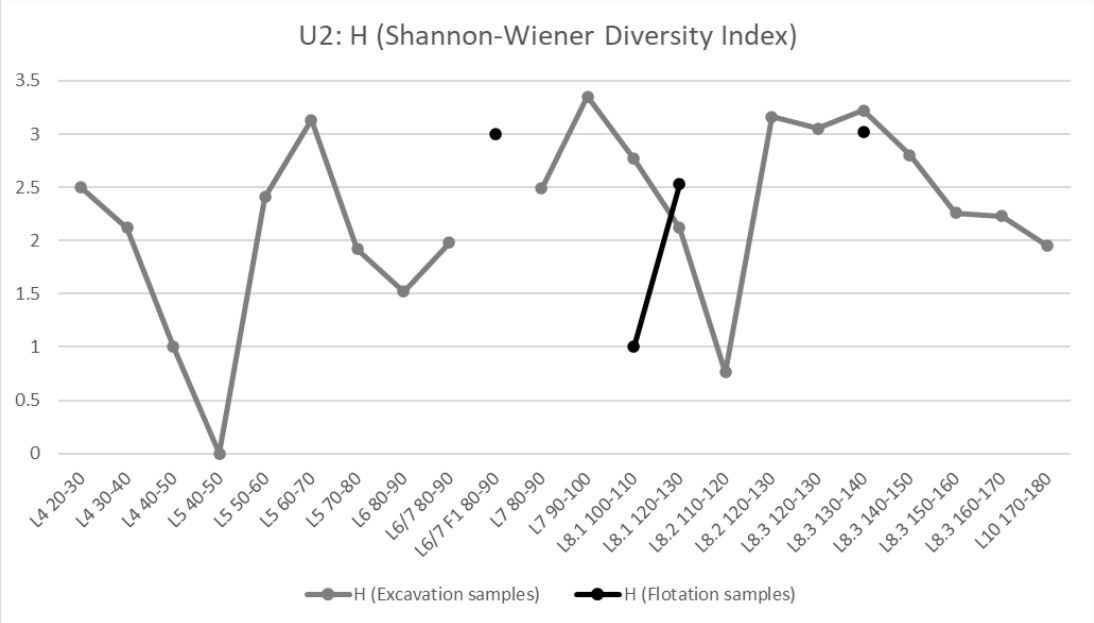


Figure 76: U2 sample's diversity index.

The highest taxa richness is observed in L8.3 (n=19, figure 75), same layer that in average show some of the highest diversity indexes (figure 76). The samples with the highest number of identified taxa (n=15, figure 75), correspond to L8.3 (130-140 cm) and to L7 (90-100 cm). This last sample has also the highest diversity Index (H=3.35).

The most frequent identified taxon is Myrtaceae type A (n=96). In terms of frequency, the most common taxa are Myrtaceae type A (14.3%), followed by *Drimys winteri* (12.6%) and *Schinus* sp. (11.3%), but as shown in figure 77 the most ubiquitous taxa are Cunoniaceae (63.3%), *Nothofagus* sp. (60%) and *Maytenus* sp. (60%).

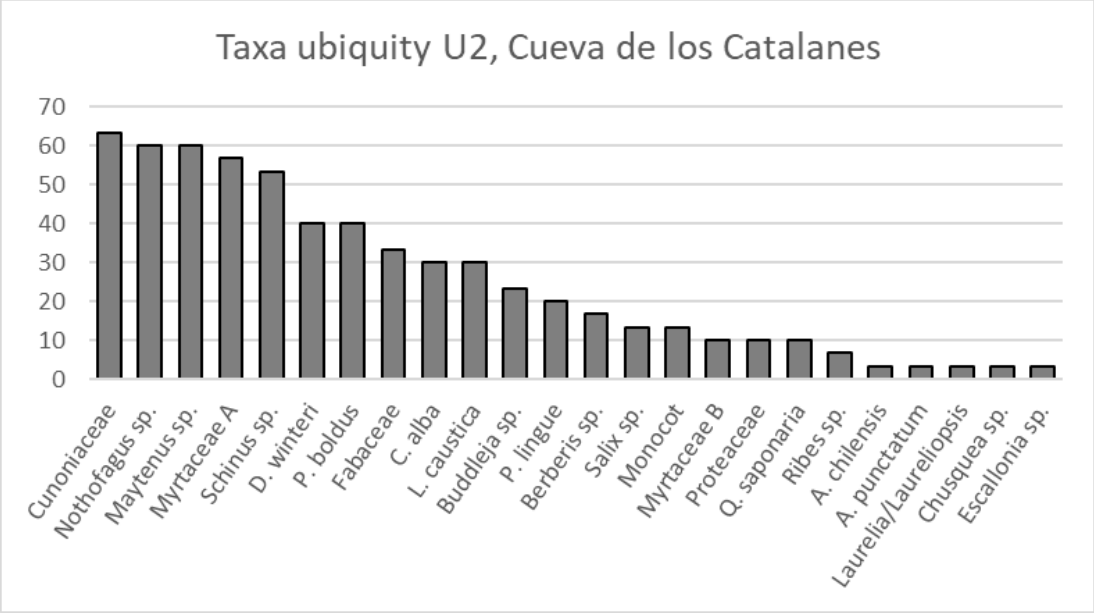


Figure 77: U2 taxa ubiquity.

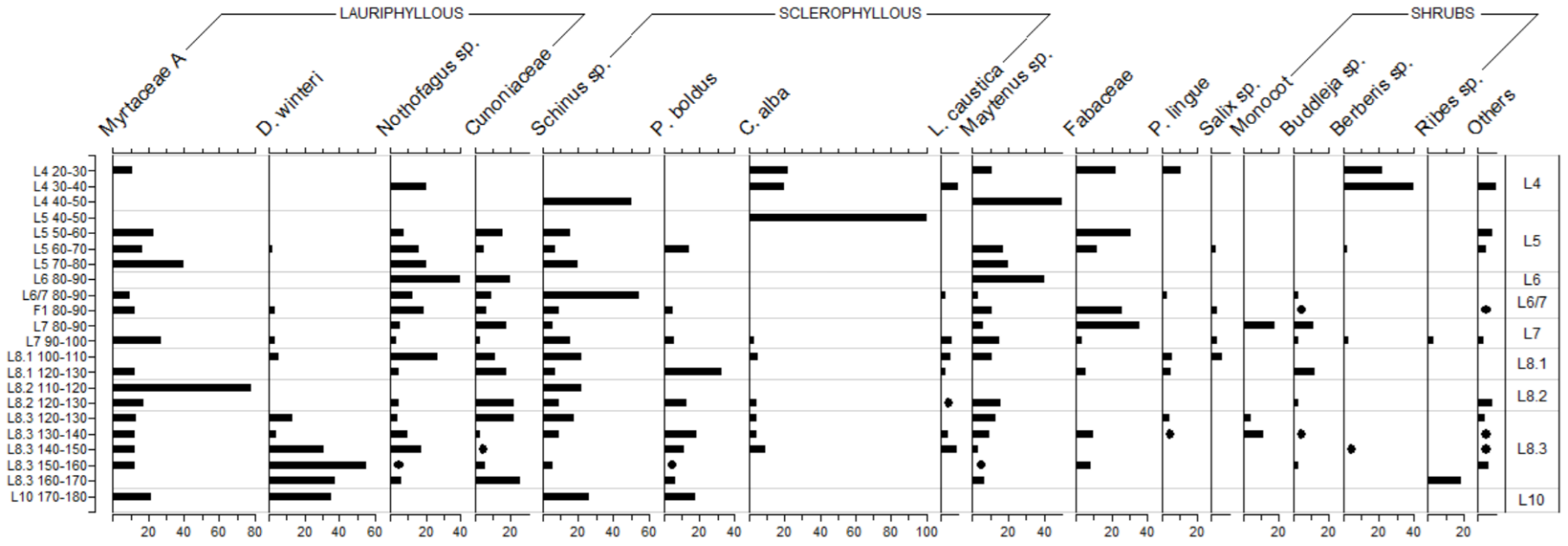


Figure 78: Relative frequency of identified taxa from U2. Circles represent values under 2.

In terms of relative frequency (figure 78), the most frequent identified taxa show variable percentages along the sequence. Myrtaceae type A, the most frequent taxon shows percentages from 10% to 75% between the 20 and 120 cm, and less than 20% between the 130 and 180 cm. The other frequent taxa (*Schinus sp., P. boldus, Nothofagus sp*., Cunoniaceae, and *Maytenus s*p.) show a similar tendency: variable percentages between 20 and 130 cm (10%-50%) and around 20% or less between the 130-180 cm. If the small size samples are not considered, the only taxon that shows a clear predominance is *D. winteri* in L8.3 between 140-170 cm.

Even though most of the identified taxa correspond to trees, smaller woody plants such as monocots and shrubs (like *Buddleja sp.,* and *Berberis* sp.) are always present in small percentages in most of the layers (except L6 and L10).

8.4.2.2 Unknown taxa

Among the 141 indeterminate angiosperm fragments, there were two types observed in different samples (table 22). Type A was already recognized in U1, while Type E was not registered before (descriptions in appendix B).

Table 22: frequency of unknown types in U2.

Unknown Fragments	L4 30-40	L5 60-70	L6/7 F1 80-90	L8.3 150-160	Total
Type A	1				1
Type E		1	3	5	9

8.4.2.3 Non-identifiable taxa

Among the 440 fragments categorized as non-identifiable, a 58.6% correspond to small size fragments (between 4 and 2 mm). About 50% of the non-identifiable fragments were categorized as such because it was not possible to observe properly the tree anatomical plains (mainly due to small fragment size or irregular shape). There are many fragments presenting more than one type of alteration (shown separately in and in table 23), but the values in this written section represent the sum of each alteration

Similarly to U1, almost a third of all the non-identifiable fragments show one or more taphonomic features (34.3%). The alterations of wood growth were registered mainly as knots (5.9%), and other anatomical issues such as small diameter/gauge were observed more frequently than in U1 (10%).

Table 23: Detail of non-identifiable fragments in U2.

Non-identifiable fragments	**Over 4 mm**		**4-2 mm**		**Total**	
	N	**%**	**N**	**%**	**N**	**%**
Presence of one or more taphonomic features	94	21.4	45	10.2	**139**	**31.6**
Alterations related to wood growth	19	4.3	4	0.9	**23**	**5.2**
Small wood gauge (twigs)	25	5.7	10	2.3	**35**	**7.9**
Presence of alterations related to wood growth and one or more taphonomic features	3	0.7			**3**	**0.7**
Small wood gauge with presence of one or more taphonomic features	7	1.6	2	0.4	**9**	**2.0**
Not possible to observe all anatomical sections	34	7.7	197	44.8	**231**	**52.5**
Total	**182**	**41.4**	**258**	**58.6**	**440**	**100**

8.4.2.4 Alterations in the wood anatomy of the assemblage

In the entire sequence of U1, 28 fragments showed anatomical alterations registered as knots. They were mainly identified in fragments over 4 mm (85.7%), and the rest correspond to fragments between 4 and 2 mm (14.3%). Most of the fragments showing knots were categorized as non-identifiable (92.8%), and only two identified taxa showed them: *Nothofagus* sp. and *Schinus* sp.

8.4.2.5 Diameter measurements of the assemblage

Diameter estimations could not be conducted due to the fragmentation of the wood charcoal samples. Nevertheless, in 51 fragments it was possible to observe a complete diameter (less than 2 cm), indicating the preservation small gauge along most of the U2 sequence. Most of the assemblage was categorized as non-identifiable and only seven fragments were identified taxonomically. Three taxa were identified: *Drimys wintery* (n=5), *Schinus sp.*(n=1) and Cunoniaceae (n=1).

8.4.2.6 Taphonomy of the assemblage

A total of 192 fragments showed at least one taphonomic feature, representing a 15.3% of the analysed wood charcoal fragments of U2. If considered separately (figure 79), the most frequent features registered was vitrification (n=152, 12.1% of U2 wood charcoal total), and in second place radial cracks (n=41, 3.3 %). These features are both related to the combustion process, and altogether they were recognized in 168 fragments (13.4 % of U2 wood charcoal

total). The presence of hyphae (H), structural collapse (SC) and infillings (I) were also registered in less proportion, and as well as observed in U1, indicators of xylophage insects were absent.

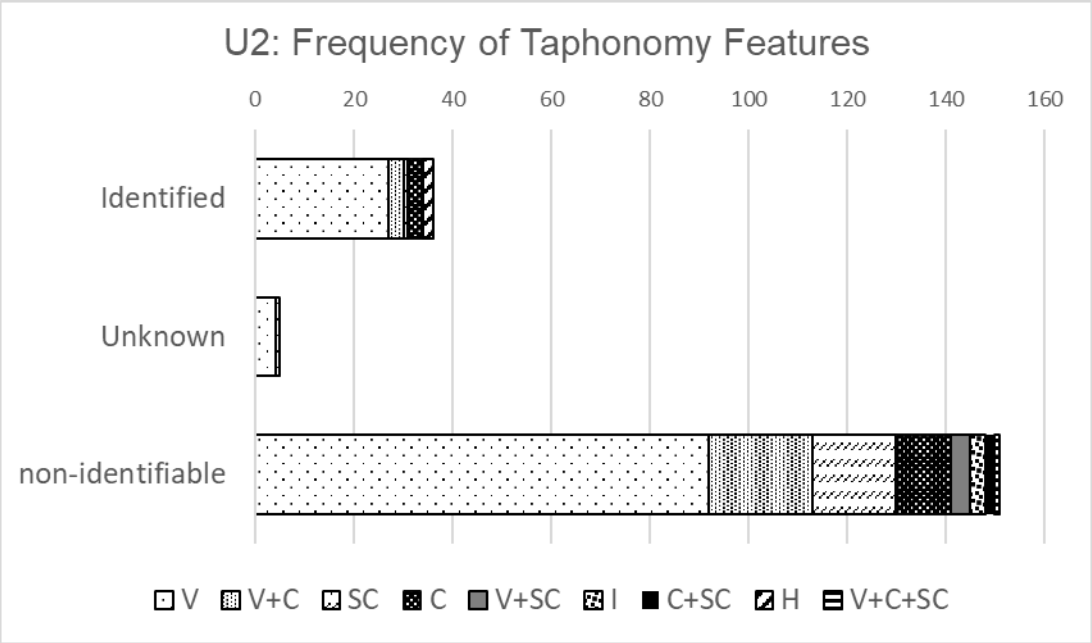


Figure 79: frequency of taphonomic features in U2 (V: vitrification, C: radial cracks, SC: structural collapse, H: hyphae, and I: infillings)

Among the identified fragments, a 5.4% showed at least one taphonomic feature, while in the unknown category it reached just 34.3%. In terms of layers and depth (figure 80), if discarding the small size samples (L4, L5 40-50, L5 70-80) the highest prevalence of taphonomic features is in L8.3 between the 130-140 cm (almost 30%). In most of the other layers, the percentages of taphonomic features show values between 10 and 20 %. The sample with the lowest percentage of taphonomic features (and adequate sample size) is L8.3 between the 150-160 cm (5.4%).

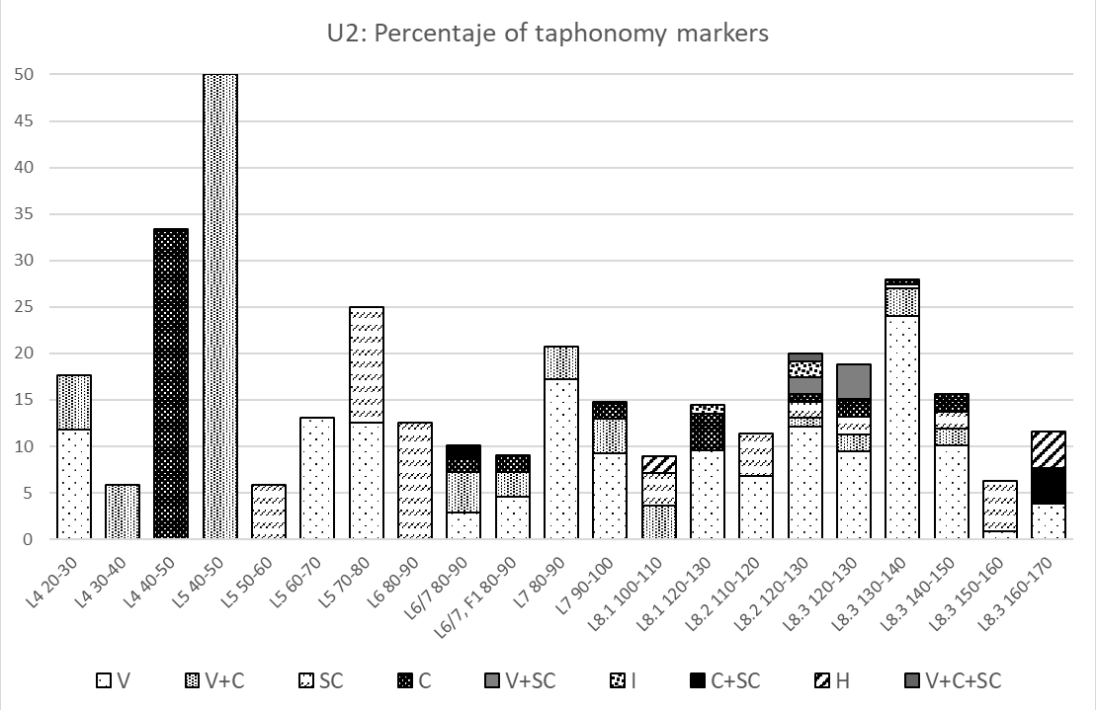


Figure 80: relative frequency of taphonomic features in U2 according to sample (V: vitrification, C: radial cracks, SC: structural collapse, H: hyphae, and I: infillings).

Since a part of the fragments showed more than one taphonomic feature simultaneously, and in comparison to U1 there are less identified fragments among them, all the taphonomy categories were included in figure 80 (see details in table 17, appendix A).

Vitrification was registered mainly on its own (n=123, 9.86% of U2), and in less proportion along with radial cracks and structural collapse (figure 81, see details in table 17, appendix A). Among the identified fragments, *Nothofagus sp*. and Cunoniance were the taxa showing vitrification more frequently.

There are few identified fragments showing radial cracks (n=6), and they correspond to four different taxa: Myrtaceae A, *C. alba, D. winteri* and *Schinus*

sp. Except for *D. winteri*, most of the identified taxa does not present wide cell rays, but they are at least 3 cells wide.

Structural collapse was registered in 26 fragments, most of them non identifiable see (details in table 17, appendix A). The only identified taxon showing structural collapse is one fragment of Myrtaceae type A. Hyphae were only registered in two identified fragments: *Drimys winteri* and *Ribes* sp. Infillings were only recognized in three fragments, all of them non-identifiable.

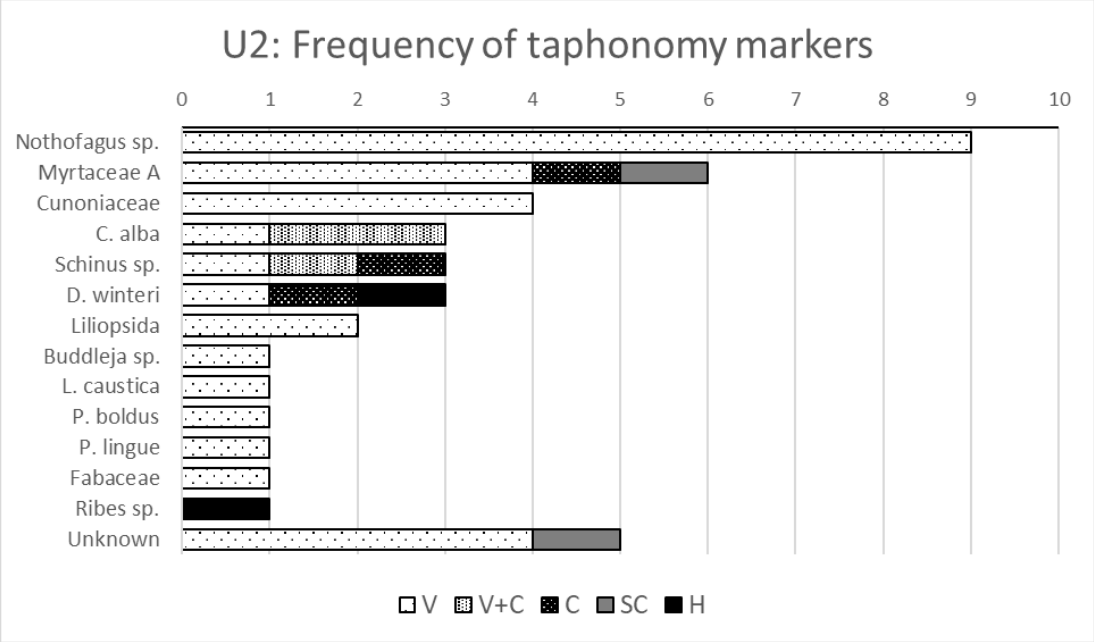


Figure 81: Frequency of taphonomic features in U2.

8.4.3 Integration of the results with previous archaeobotanical information of the site

The previous archaeobotanical analysis of the sites included charred seeds and micro remains (see the detailed list in table 18, appendix A). The macro remains were mainly obtained through the flotation of the sediment columns from U1 and from the excavation samples of U2. The micro remains were also obtained from bulk sediment samples collected from U1 and U2 (Roa Solís & Zurro 2022), and in less amount from direct scraping of ceramic fragments and smoking pipes (Godoy-Aguirre 2017).

In general terms, the microremains results show low rates of taxonomical identification. Among the samples taken by the scaping of artifacts, most of the identified taxa was obtained from materials ascribed to the ECP, including some starch grain of *Aristotelia chilensis* and possible starch grains of cf. *Zea mays* and cf. *Nicotiana* sp. Most of the samples show starch grains, phytoliths and other tissues identified as Monocots during the ECP, LCP and HP.

The analysis from the bulk sediment samples considered blank samples, ashes concentrations, and hearths (Roa Solís & Zurro 2022). The samples were obtained in a more systematic way that allowed the comparison between different periods, but they were focused on phytoliths analysis. Most of the identified morphotypes in the site corresponded to Monocots, and in comparison to the HP, the pre-Hispanic samples show more abundance of vegetal tissues indicating the processing and refuse of plants in situ.

During the ECP the low heterogeneity of the samples suggest a regular occupation of the Cave that could correspond to short term use of the cave, but redundant over time and probably related to a seasonal use of the site. In contrast, during the LCP the heterogeneity of the samples suggests a less intensive occupation of the cave or less redundant over time. There is a more significant proportion of Dicot plants, interpreted as an intensive use of woody plants during the LCP.

Among the macro remains, 30 different taxa were identified including cultivated plants, herbaceous perennials and woody taxa (Roa Solís *et al.* 2024, Roa *et al.* 2018). Among the woody plants, seven different taxa were identified, six of them representing native families to Southern Chile, and one corresponds to an exogenous species (*Acacia dealbata).* Three of the native woody taxa were also identified among the wood charcoal fragments (*A. chilensis, C. alba*, and *Nothofagus sp*.), and the other three were identified among the wood charcoal at a different taxonomical level. The only woody species identified from charred seeds in all the Periods are *C. alba and A. chilensis,* while *C. alba* was also identified in all Periods among the charcoal fragments, A. chilensis was only identified in the pre-Hispanic Periods as wood charcoal. For Anacardiaceae, cf. *Sophora sp.,* and *Nothofagus sp.*, their wood charcoal comparable taxon (*Schinus* sp., Fabaceae, and *Nothofagus sp*., respectively) was registered in all the Periods. While cf. *Gevuina avellana* was only recovered as charred seed in pre-Hispanic Periods, wood charcoal fragments identified as Proteaceae were registered in the ECP and HP. This reinforces the complementary of wood charcoal and charred seed analysis, which in this site provides a wider

chronology of use for the identified vegetal taxa. Since most of the woody taxa produced fruits and seed in summer and early spring, this could also indicate a possible aestival use of the cave. Nevertheless, it is also important to keep in mind that *C. alba* could have been introduced to the cave by animals (like foxes, *Lycalopex* sp.) and *A. chilensis* could have also been introduced by birds or rodents.

In relation to the exogenous seeds identified in the HP, is important to mention that although charcoal fragments of the Fabaceae were also identified in the HP, they do not correspond to *Acacia dealbata*, but more likely to a native species (probably *Otholobium or Shopora*).

In relation to the cultivated taxa, quinoa is the only taxon present in all the periods. The common bean (*P. vulgaris*) and maize were registered in both pre-Hispanic periods, chilli (*Capsicum sp.)* was only registered in the LCP, and *Triticum* sp. was only identified in the HP.

8.5 Cueva de Los Catalanes discussion of the archaeobotanical assemblage

One of the concerns at the moment of interpretation, is that there is no certainty about the use of the cave during the LCP. As mentioned before, the zooarchaeological material and the phytolith record suggest a less intensive occupation of the cave or less redundant over time for LCP in comparison to the ECP (Roa Solís & Zurro 2022, Zúñiga 2021). The taphonomy of the wood charcoal could also suggest a similar scenario. In comparison, the ECP shows a higher percentage of taphonomic features (22.5%) than in the LCP (17.4%) and HP (15.1%). This could be interpreted as a result of a more intensive and recurrent use of the cave during the ECP (trampling), either seasonally or sporadically.

Altogether the archaeological material evidence sugests food preparation and consumption in the cave, but it is not possible to establish if there was a ritual or symbolic aspect to those activities. During the HP, the cave was likely used as shelter or resting place for cattle herding.

In order to facilitate the discussion and estimate a broader image of the forest environment around the site, the taxa results were grouped in the Cultural Periods already defined by the stratigraphy and radiocarbon dates of the site. To explore possible changes in the vegetation types, and for comparison purposes the Myrtaceae types A and B were grouped together as Myrtaceae, and all the shrub taxa were also grouped together.

For the ECP a sum of 528 identified fragments were considered, and a total of 22 different taxa were identified. The predominant taxa are the Myrtaceae family (18.2 %), *D. winteri* (15.3%), *P. boldus* (11.4%) and *Schinus sp*. (10.4%). There are two identified taxa (*Chusquea* sp. and *Escallonia sp.)* that are absent in the other Periods (although only one fragment of each taxon was identified in the ECP). In comparison, the taxa missing in the ECP but registered in the other Periods are *A. punctatum* and *Salix* sp.

In the LCP a total of 676 wood charcoal fragments were counted, corresponding to 21 woody taxa. The most registered taxa were the Myrtaceae family (21.4%), *D. winteri* (12.7%), the Fabaceae family (10.9%), and *Nothofagus* sp. (10.1%). Apart from the two taxa only registered in the ECP, Proteaceae is the only taxon missing in the LCP but present in both other Periods.

The HP is the one with the smallest number of identified fragments, with a total of 196 that corresponds to 18 woody taxa. As well as in the previous Periods, the Myrtaceae family is the predominant taxon (33.2%), followed by Nothofagus sp. (15.8%) and the Fabaceae family (7.1%).

In comparison, the wood charcoal from both pre-Hispanic periods shows a similar number of taxa and a similar diversity index value, while the lowest diversity index value and among taxa richness is found in the HP (figure 82). Among the charred seeds, the LCP shows higher taxa richness in comparison to the ECP and HP (23 versus 16 and 17 respectively, Roa Solís *et al.* 2024).

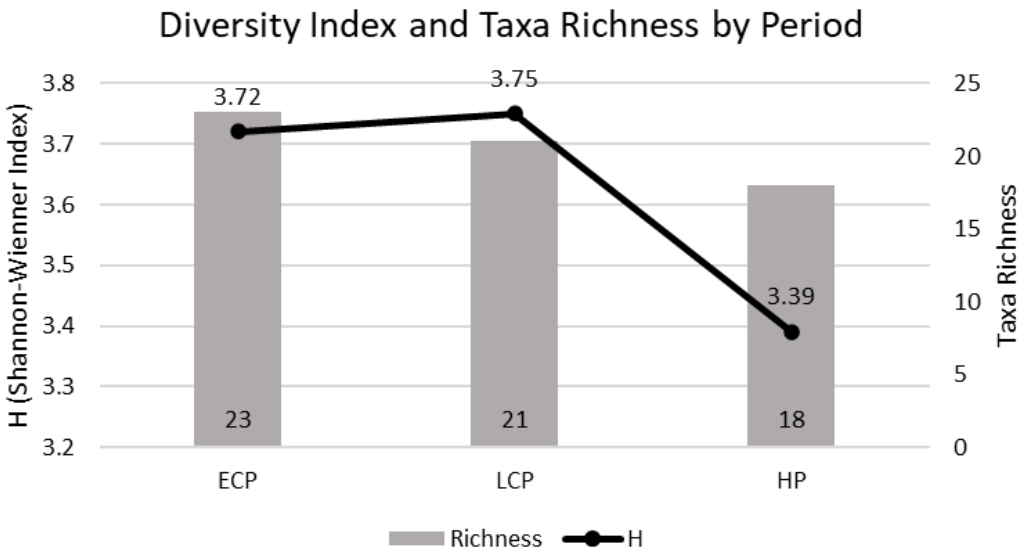


Figure 82: H (Shannon-Wienner index) and taxa richness by Periods.

From an ecological perspective, in all the three periods there is presence of lauriphyllous and sclerophyllous taxa, as well as secondary shrubs (figure 823. There is a predominance of lauriphyllous taxa in all the periods, while in both pre-Hispanic periods they represent around 50% of the wood charcoal, in the HP it reaches 60%. The sclerophyllous taxa show a different tendency, decreasing its representation from a 30.7% in the ECP, to 20.8% in LCP and 13.3% in the HP. It is important to mention that most of the identified sclerophyllous taxa correspond to late successional species and genera, so its decrease along the sequence suggest lower regeneration rates for this type of vegetation. Other taxa like shrubs, monocots and *Maytenus* sp. seem not to show much variation along the sequence, keeping similar values in each of the Period.

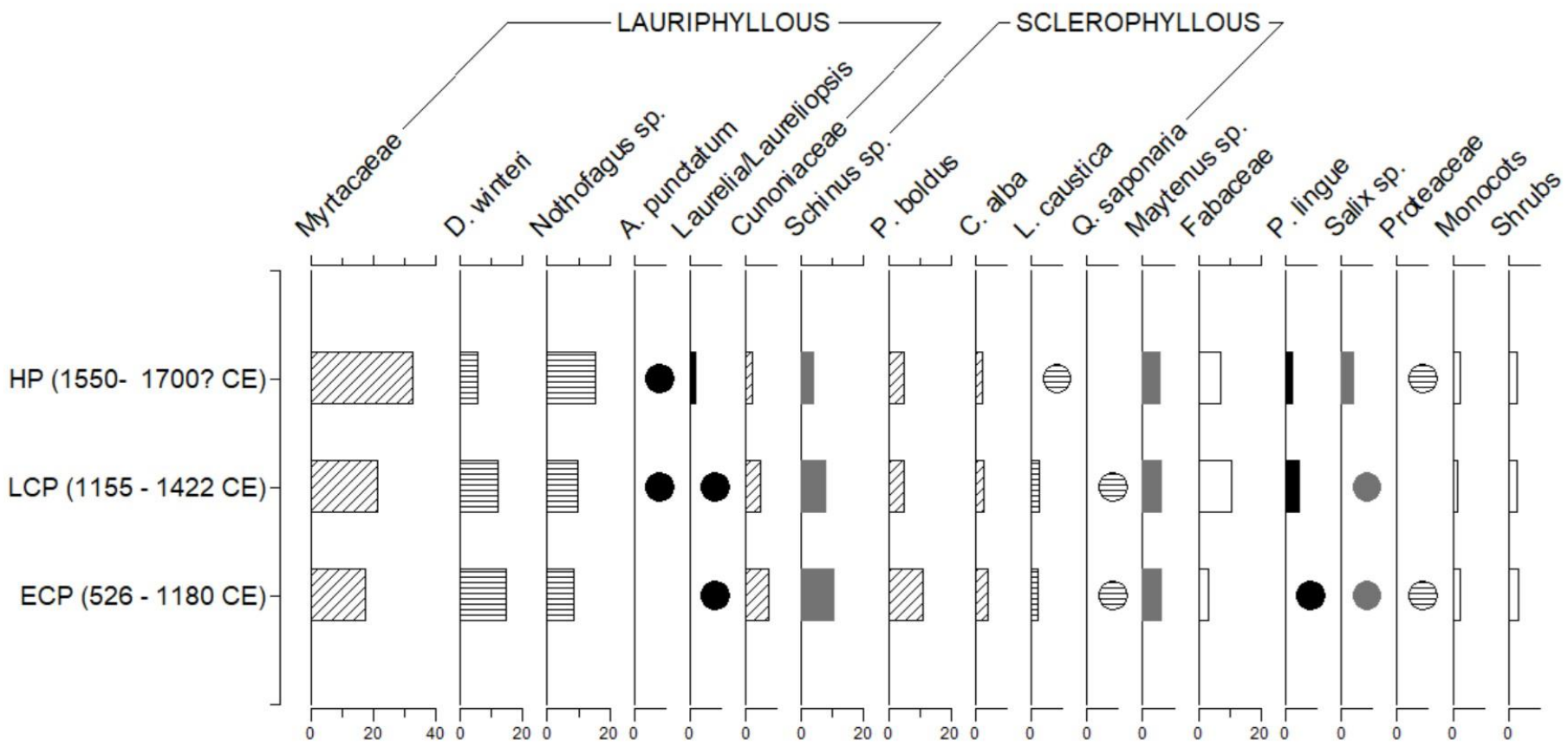


Figure 83: Summary of Identified Woody taxa from Cueva de los Catalanes according to ecology. Black filling indicates shade tolerance, striped diagonal filling indicates shade tolerance to medium, striped horizontal filling indicates shade intolerance to medium tolerance, grey filling indicates shade intolerance. Unfilled or white colour indicates no specific shade/light tolerance. Circles indicates values under 2%.

In terms of shade tolerance and forest succession, the shade tolerant taxa (*A. punctatum*, *Laurelia/Laureliopsis, and Persea lingue)***,** represent between 2% and 7% in the different periods. If grouped together with shade tolerant to medium tolerance taxa (Myrtaceae, Cunoniaceae, *P. boldus*, and *C. alba*) the percentages reach 43.9 % in the ECP, 42% in the LCP and 49.5% in the HP. The shade intolerant taxa (*Shinus* sp. and *Mytenus* sp.) represent between 9% and 16% along the sequence. But, if grouped with shade intolerant to medium tolerant taxa (*D. winteri*, *Nothofagus* sp*., L. caustica, Q. saponaria* and the Proteaceae family), they represent 45.6% in the ECP, 41.3% in the LCP and 33.7% in the HP. Other taxa like *Salix* sp. have been described as pioneer in water saturated areas like riverbanks, showing only presence from the LCP, but with a relative increase in the HP (0.6% to 3.6 %). These results indicate an equilibrated distribution between the shade tolerant and shade intolerant taxa in the pre-Hispanic Periods, and a slight prevalence of shade tolerant taxa in the HP.

Considering the ecology, shade tolerance, diversity and taxa richness, the pre-Hispanic wood charcoal record does not indicate a significant difference between the ECP and LCP. The more noticeable differences are observed in the HP, when there is a predominance of lauriphyllous taxa and more shade tolerant taxa.

8.6 Summary of Cueva de los Catalanes results and interpretations

A sum of 24 woody taxa were identified in the samples from U1 and U2 of Cueva de los Catalanes, representing 19 families of native angiosperms. Although there is presence of shrubs and other minor species like monocots, the anthracological spectrum of the site was dominated by tree taxa. The most frequently identified and ubiquitous taxon was Myrtaceae type A.

In terms of chronology, the site represents three Periods: the ECP, LCP and HP. Most of the recovered evidence comes from the pre-Hispanic periods, and although the sample for the HP is small, some trends were observed. During both pre-Hispanic Periods there is a balanced distribution between the shade tolerant and shade intolerant taxa, but a slight prevalence of shade tolerant taxa was observed in the HP. Also, sclerophyllous taxa tended to decrease from the ECP to HP, and since most of them correspond to late successional taxa, this could indicate during this last period there were no favourable conditions for the regeneration of this type of forest.

Chapter 9: El Arenal-1

9.1 Geographical and archaeological context

El Arenal-1 (WGS84, UTM 18H 622862E / 5863012S) is a coastal open-air archaeological site located in the Arauco Province, Biobío Region. The site is located about 2 km east from the coast, between the northeastern border of the Yani sand dunes and a partially vegetated wetland (south of the Quidico Stream). In Spanish, *arenal* means a sandy place or a spot full of sand (figure 84).



Figure 84: General view of El Arenal-1, (photo courtesy of C. Roa, 2018).

The Yani dunes are an active dune system with drastic seasonal changes. During the cold and wet months (May to August), various water streams, wetlands and flood plains became active. The site is located in one of the

floodplains, and the flooding episodes seemed to have contributed to the preservation of the organic archaeological materials of the site (Buhring 2020). The deposit of the site corresponds mainly to sand and wet materials, and because of the active environmental conditions, the cultural deposit could have been shifted down, as well as dispersed and subjected to compaction (Buhring *et al.* 2023).

The site was initially registered in 2002 and excavated between 2003 and 2007, by a similar team of the early Mocha Island excavations. Initially, three Thermoluminescence dates were obtained. The earliest one dated to the Early Ceramic Period (700±130 CE), and it was obtained from a layer without typical Late Ceramic types. The rest of the dates indicate a Late Ceramic Period occupation that could extend into the early Historic period. The site was controversial because among the bone assemblage chicken remains of at least three individuals were identified (it was not specified if the samples were identified as *Gallus gallus* or *Gallus sp.,* Storey *et al*. 2013). Three radiocarbon dates were obtained from the chicken bones and DNA was also conducted, and although the authors indicate that there is enough evidence to support a pre-Hispanic dispersion of chicken from the Polynesia, the current consensus is that chickens were introduced after the Spanish arrival (Gongora *et al.* 2008).

Most of the recovered archaeological material represents a Late Ceramic domestic context where "*El Vergel*" diagnostic ceramic types are present (Contreras *et al.* 2005). In functional terms, the ceramic assemblage corresponded mainly to cooking pots and storage jars (*urnas*). The

zooarchaeological assemblage indicated a broad-spectrum resources consumption that included fish (with predominance of *Trachurus symmetricus*, the Pacific Jack mackerel), terrestrial mammals (camelids, *Pseudolopex griseus, Myocastor coipus* and other small rodents), marine mammals (Cetaceae), birds and amphibians (although there the absence of cut marks could indicate a post-depositional origin of these remains). Among the vegetal remains, *Chenopodium quinoa* was the most frequently recovered taxa, associates in some features with *Typha agustifolia*. Maize was recovered in small quantities (n=5), and among the native taxa, *Rubus* sp. and *Cryptocarya alba* were identified (Silva 2010).

Besides the chicken controversy, the excavation of the site was relevant in the history of Southern Chile Archaeology, because it was one of the first continental habitational sites analysed for the Late Ceramic Period.

In 2018 the site was relocated and reassessed by a new archaeological team as part of the Doctoral project of K. Buhring, University of Auckland, New Zealand. During that opportunity, 38 core tests and 9 test pits were dug. Four radiocarbon dates were obtained indicating an occupation of the site from 13th to 16th centuries, confirming its Late Ceramic Period and early Historic Period adscription (Buhring 2020). From this excavation, no other diagnostic material or dates of the Early Ceramic Period were recovered, or any evidence of chicken bones.

The archaeological materials from the latest excavation of the site indicate a habitational context as well (Buhring *et al.* 2023). The ceramic assemblage

shows presence of red over white decoration (“El Vergel” type), thick fragments characteristic of storage jars, fragments from jugs and necked pots, and fragments with evident fire exposure (soot adhered to surfaces). Among the lithic materials, one obsidian projectile point was recovered. According to the geochemical characterization the obsidian source corresponds to Portada Covunco, in the Argentinian Patagonia. As it was also observed in Mocha Island, this suggests wide interaction networks during the LCP in Southern Chile.

A sum of 17 different taxa were recognized in the zooarchaeological material from the excavation. As well as in the previous excavation and although the sample was small, a hight diversity of taxa was identified indicating a broad range of faunal resources consumed in the site. To summarize, the identified taxa consist of marine and terrestrial mammals (including camelid´s bones with butchering marks), rodents, small carnivores, reptiles, amphibians, fish and birds. Among the birds, tinamou *(Nothoprocta perdicaria*) was recognized, taxon unreported in the previous analysis but common in other sites of the Period. A reassessment of some of remains from the earlier excavations identified as chicken indicate that they were actually Tinamidae. This was also supported by DNA analysis of “potential chicken” samples from the latest excavation, which showed affiliation with tinamou instead of chicken. The malacological assemblage showed a predominance of gastropods (bivalves were also registered), suggesting a consumption of locally available marine resources found in sandy and in intertidal coastal zones.

The archaeobotanical analysis considered flotation samples obtained from the exposed profiles of two of the excavation units. Among the cultivated plants quinoa and maize were identified, and among the native taxa, grasses were identified (*Bromus* sp. and undetermined Graminae), berries (*Aristotelia chilensis*, cf. *Fragaria chiloensis*, and *Rubus* sp.), and other native plants (*Madia sativa*, *Chenopodium* sp., and cf. *Gaultheria* sp.). The most ubiquitous taxa were quinoa, maize, wild raspberry and Graminae. By comparing the results from both exactions and archaeobotanical analysis, seven previously unreported taxa were identified in the latest analysis. Nevertheless, there also two taxa previously reported and not identified in the latest analysis: *Cryptocarya alba* and *Typha agustifolia (Roa 2019, Silva 2010).*

Altogether, the reassessment of the site did not provide evidence supporting a transpacific interaction as initially proposed after the first excavation of the site (Buhring *et al*. 2023).

9.2 Material provenience, stratigraphy and chronology

The analysed wood charcoal samples come from the 2018 excavation fieldwork, when 32 test cores, six test pits (TP1 to TP6), and three excavation units were done (TP7, TP8, and TP9). The test pits dimensions were 50x50 cm and 100x50 cm, and the excavation unit's dimensions were 100x100 cm. The analysed samples were obtained from TP2, TP4, TP5, TP6, and from the excavation units TP7, TP8 and TP9. As can be observed in figure 85, while

TP5 to TP9 are closer to the edge of the mobile sand dune (left side on figure 85), TP2 and TP4 are further away from them.

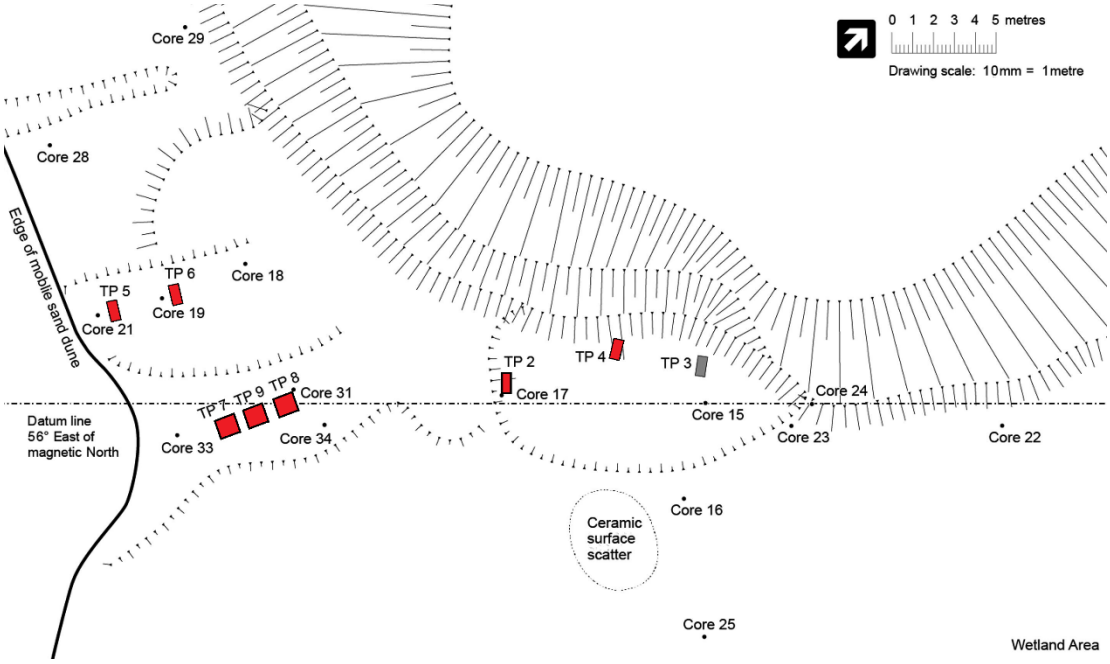


Figure 85: Excavation plan from 2018´s excavations (modified from Buhring et al. 2024). Red figures indicate test pits and excavation units from which wood charcoal samples were obtained.

A total of 32 excavation samples were analysed, obtained in a non-systematic way from test pit units TP2, TP4, TP5, TP6, TP7, TP8 and TP9 (details in table 19, appendix A). Each sample was given a unique sample code, and a corresponding context code. More than one sample can share the same context code, and although each context was linked with individual Test pits and Layers, there are samples with missing information.

There were eleven flotation samples only obtained from TP7 (six samples, 15.85 litres) and TP8 (five samples, 8.9 litres). Unfortunately, there is not much information about the sampling process, but apparently the sediment samples

were obtained from the exposed profile of the excavation units, and they were floated using the bucket method (details in table 19, appendix A).

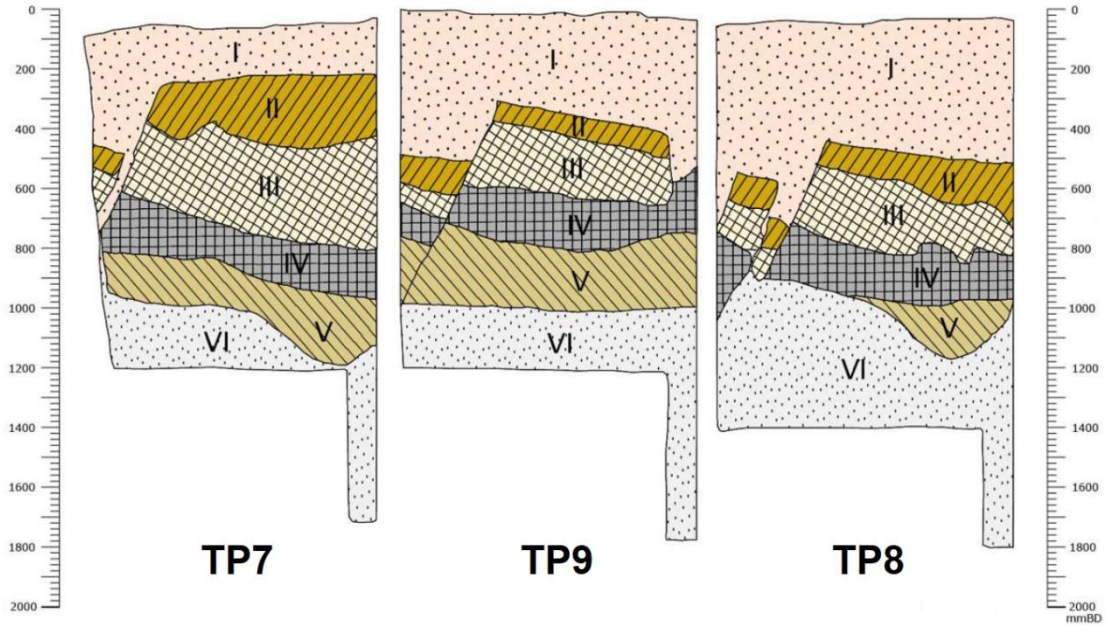


Figure 86: Stratigraphy TP7, TP9 and TP8, modified from Buhring et al. 2024.

Light and heavy fraction were bagged separately and sorted under a binocular microscope (7-45 X). The wood charcoal from the flotation samples was sieved and separated by size (over 4 mm, between 4 and 2 mm, and under 2 mm), and then weight according to size.

In terms of stratigraphy, six sediment layers were recognized during the 2018 excavation (named Layer I to Layer VI), representing four main cultural phases. The description of each layer is summarized in table 24, and as it can be observed in figure 86, a continuous stratigraphy was observed in the TP7, TP8 and TP9 (located almost adjacent to each other, figure 85).

Table 24:El Arenal-1 Stratigraphy (own synthesis based on descriptions by Buhring 2020).

Layer I (sterile): unconsolidated fine grain sands located under the superficial grass cover. The sands are yellow brown, and they are probable of a local origin. Some mud content suggests flooding events. Archaeological material: none.
Layer II: Very fine sands of dark brown colour. The matrix was formed by sands derived from the nearby dunes with a contribution from the river (volcanic materials probably added during past floodings). Main archaeological material: ceramic, bone, shell, charcoal. One AMS date was obtained from this layer in TP7
Layer III: Very fine sands of dark colour with an increase of mud and organic material. The Layer seems to be a mixture of dune and alluvial materials. Main archaeological material (abundant in comparison to previous layer): ceramic, bone, lithic, shell, charcoal. One AMS date was obtained from this layer in TP7
Layer IV: Similar to Layer III, but with less organic components. Main archaeological material: ceramic, bone, and shell.
Layer V: Similar to layer IV, but some inclusions of brown mottled sand was observed. Main archaeological material: ceramic, bone, shell, lithic, and charcoal. Two AMS dates were obtained from this Layer in TP7.
Layer VI (sterile): Light-yellow sand Sandy. Archaeological material: none.

Of the seven available ^{14}C dates (Buhring *et al.* 2023), there is no stratigraphical information for the three chicken bone samples (Storey et al. 2013). Among the four most recent ones, there is one taxon date for *Zea mays*, and the remaining three all correspond vegetal samples of short-lived specimens (including Monocot tissue and 3mm diameter stems). All dates were recalibrated, and as was done in the previous analysed sites (figure 87), the calibration was done in OxCal 4.4 using the SHCal20 calibration curve (Hogg *et al.* 2020).

Altogether, the dates indicates that the site was inhabited between the 1317 to 1590 cal. CE (details in table 20, appendix A). Considering the available stratigraphic position of the dates, it is not possible to differentiate chronologically each of the Layers identified in the site. Although Layer V provided one of the earliest dates (1332-1425 cal. CE), the maize sample from the same layer gave a younger date (1457- 1512 cal. CE). Since the deposit corresponds to sand, and the site is located next to an active dune system, the dates are coherent with a complex depositional environment.

The Arenal-1 radiocarbon dates indicate a LCP occupation. Even though the dates could extend to the first decades of the Spanish conquest, there is no material evidence to support a clear post-Hispanic occupation of the site. Nevertheless, and as well as observed in the sites of Mocha Island, the absence of typical Hispanic or Historical materials does not necessarily imply that the site was not occupied during the Historical Period.

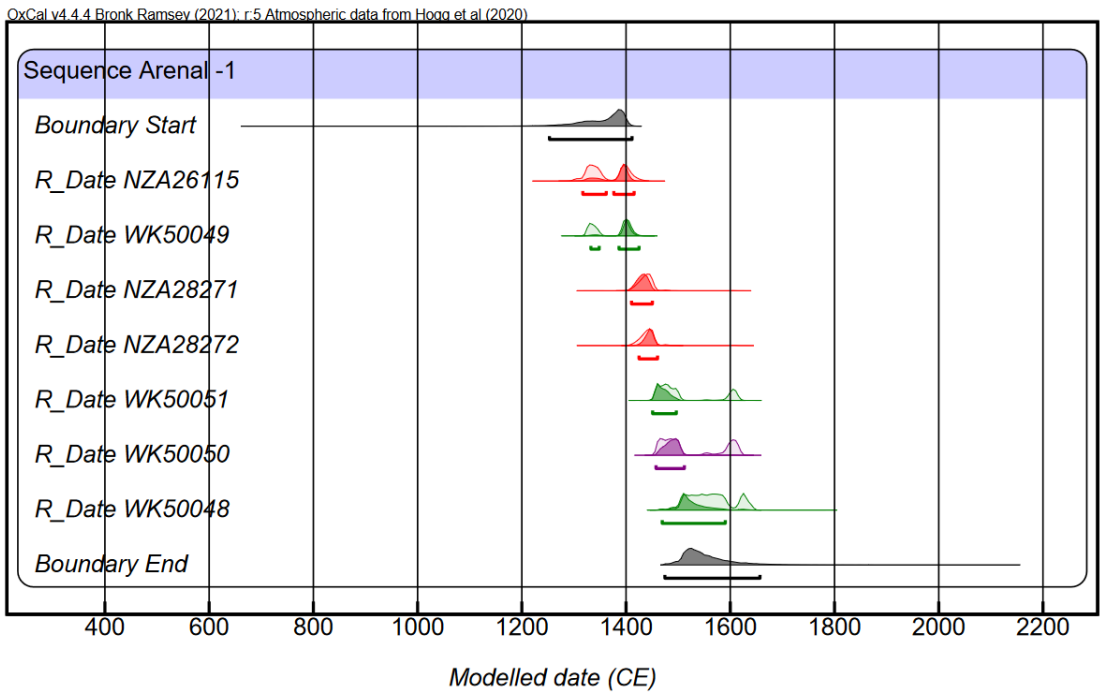


Figure 87: ^{14}C dates of El Arenal-1. Colours indicate sampled material: red= animal bones (reported as chicken bones by Storey et al. 2013), green= vegetal tissue (monocot tissue and twigs), purple= seeds/crops (maize).

9.3 Wood charcoal analysis results

A sum of eleven flotation samples, and 32 wood charcoal samples from the excavation were analysed. Considering the weight of the samples, most of the analysed wood charcoal correspond to handpicked samples recovered during the excavation (80.38 gr versus 12.27 gr recovered through flotation. See details in table 19, appendix A). Even though the samples are not directly comparable (no systematic sampling was applied), most of the wood charcoal was recovered from the TP7 samples. There was only one sample without context information from TP4 (so it was not ascribed to any layer), and although the sample is not included in most of the following figures, it is considered in the main counts. Even though it was already mentioned that in chronological

terms is not possible to differentiate the layers, they are used in order to present the data in a more organized way.

In terms of weight, most of the wood charcoal recovered through flotation corresponds to fragments over 4 mm (38.1%), and between 4-2 mm (34.5%). Overall, the distribution of the size categories does not suggest significant conditions affecting the fragmentation of the samples. Nevertheless, a higher percentage of bigger fragments (over 4 mm) was observed in the samples from Layer IV, TP8 (figure 88). The smallest fragments (under 2 mm) were recovered in slightly higher percentages in Layer II, TP8. Altogether, Layer IV shows the highest amount of recovered wood charcoal from flotation samples.

Among the excavation samples (figure 89), most of the recovered wood charcoal comes from TP9 (22.02 gr) and TP7 (21.82 gr). Considering the samples by layer, most of the wood charcoal was recovered from Layer III (27.72 gr) and Layer V (25.41 gr). While Layer III groups samples from all the test pits and excavation units, in Layer V there are samples just from TP7 and TP9, but abundant in wood charcoal. In terms of size, most of the wood charcoal fragments correspond to the over 4 mm category (67.7%), which is not surprising since they correspond to handpicked samples.

A total of 2180 carbonized remains were analysed. Among them 2127 wood charcoal fragments and three bark fragments were identified. There were also other 51 fragments of an indeterminate vegetal tissue, but they were not considered in the final count. In total 1104 wood charcoal fragments were

identified (51.9 %), 172 were categorized as unknown angiosperm (8.1%), and 851 were classified as non-identifiable (40%).

Considering the only the flotation samples, Layers III and IV show the highest percentages of identified fragments (56.2 % and 62.9% respectively). By also considering the Test Pit, TP7 shows the highest percentage of the identified category in Layer IV (70.1%, figure 90). The layers with highest percentage of non-identifiable fragments are Layer II and V from TP8, but this percentages are not significant because of the small sample size in these layers.

Among the excavation samples, Layer III, IV and V show over a 50% of the identification category (figure 91). Layer II has the highest percentage of the non-identifiable fragments (65.6%). By considering each Test Pit, and well as observed in the flotation samples, TP7 shows the highest identification rate in Layer IV (66.7%). TP7 also shows the highest proportion of non-identifiable fragments in Layer II (68.4%), but this time the sample size is not an issue as in the flotation samples. In the taphonomy section it will be discussed if the incidence of certain alteration could explain this high rate of non-identifiable fragments. Unlike the Mocha Island sites, modern agricultural disturbance is less likely to have affected the more superficial layers of the site. Preliminarily, and since the site is part of an active system of dunes, the more superficial layers could have been more exposed to mechanical alterations. This is just a preliminary hypothesis that should be contrasted using comparative analysis that consider all the other archaeological types of evidence recovered in the site.

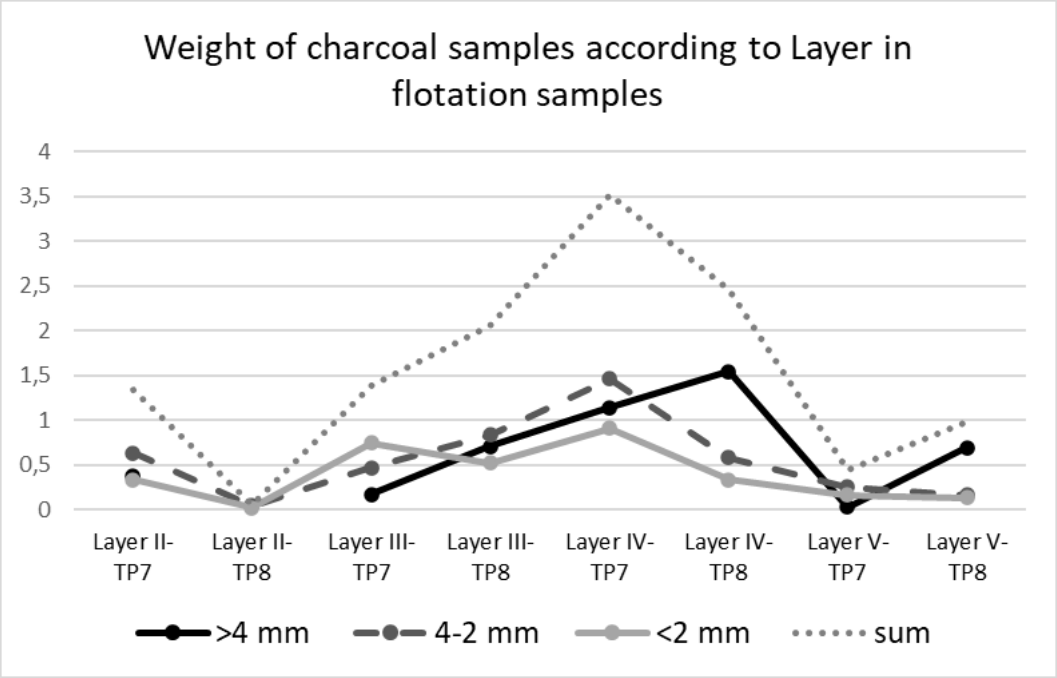


Figure 88: Weight of flotation samples from TP7 and TP8 according to Layer.

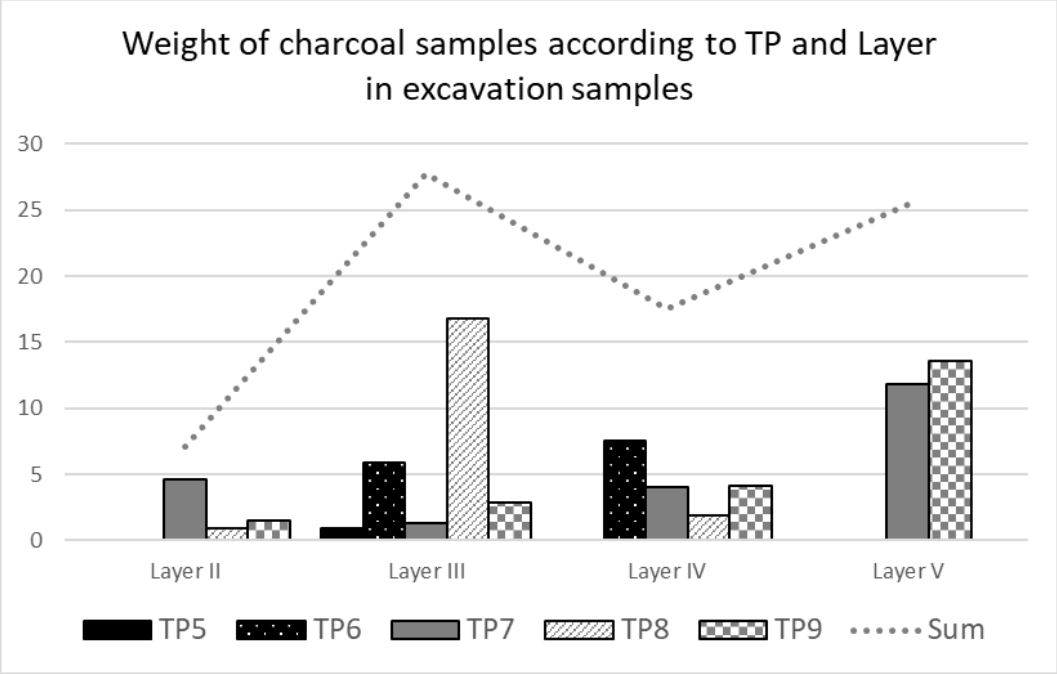


Figure 89: Weight of excavation samples from El Arenal-1 according to layers.

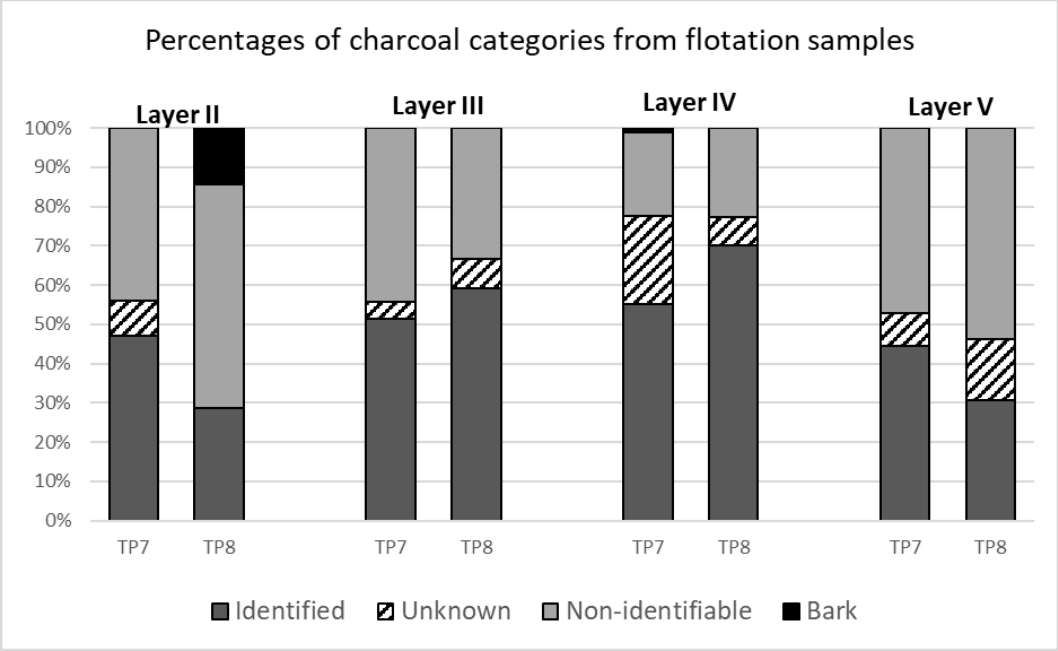


Figure 90: Percentages of identification categories from flotation samples.

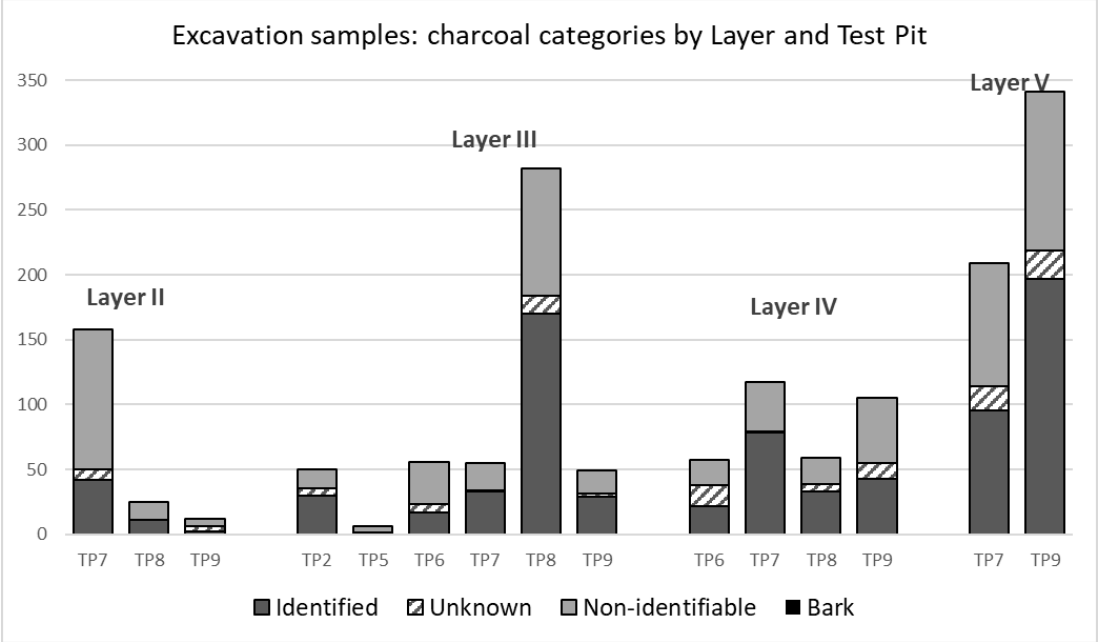


Figure 91: Frequency of identification categories from excavation samples.

9.3.1 Identified taxa

A total of 24 taxa were recognized, including one conifer taxa (identified to class level as Pinopsida) and 23 angiosperm taxa. Among the angiosperms, only one taxon was identified to class level as monocots (Liliopsida). Of the remaining 22 dicots taxa, four were identified to family level, two to subfamily level, seven to genus level, and nine to species level. Altogether, the identified taxa of the site represent 17 angiosperm families of native woody taxa (table 25).

Table 25: El Arenal-1 identified taxa.

Class	**Family**	**Genus/species**	**N**	**%**	**U**
Pinopsida (Conifers)			4	0.4	2.3
Liliopsida (Monocots)			15	1.4	13.9
Magnoliopsida (Dicots)	Aextoxicaceae	*Aextoxicon punctatum*	23	2.1	25.6
	Anacardiaceae	*Lithrea caustica*	3	0.3	7.0
		Schinus sp.	1	0.1	2.3
	Berberidaceae	*Berberis* sp.	2	0.2	2.3
	Celastraceae	*Maytenus* sp.	2	0.2	4.6
	Cunoniaceae		37	3.3	37.2
	Elaeocarpaceae	*Aristotelia chilensis*	4	0.4	7.0
	Fabaceae		1	0.1	2.3
	Grossulariaceae	*Ribes* sp.	8	0.7	16.3
	Lauraceae		8	0.7	13.9
		Cryptocarya alba	8	0.7	9.3
		Persea lingue	38	3.4	13.9
	Monimiaceae	*Laurelia/Laureliopsis*	17	1.5	18.6
		Peumus boldus	83	7.5	58.1
	Myrtaceae	Type A	69	6.2	46.5
		Type B	738	66.8	88.4
	Nothofagaceae	*Nothofagus* sp.	3	0.3	7.0
	Onagraceae	*Fuchsia magellanica*	3	0.3	4.6
	Proteaceae		20	1.8	20.9
	Quillajaceae	*Quillaja saponaria*	8	0.7	11.6
	Scrophulariaceae	*Buddleja* sp.	5	0.4	11.6
	Winteraceae	*Drimys winteri*	4	0.4	4.6
Total			1104	100	-

The highest taxa richness is observed in Layer III (n=27, figure 92), and the layer showing the highest diversity index is Layer II (H=2.43, figure 93). In terms of each Test pit, the highest taxa richness is observed in Layer III from TP8 (n=15), but the highest diversity Index is in Layer II from TP7 (H=2.31).

The most frequent identified taxon is by far Myrtaceae type B (66.8% of identified fragments). Other important taxa, but notoriously less frequent, are *Peumus boldus* (7.5%), Myrtaceae type A (6.2%), and the Cunoniaceae family (3.3%). Myrtaceae type B and the last three taxa also show the highest ubiquity (figure 94). It is also important to mention that the conifers fragments were only registered in the sample from TP4 which does not have a layer adscription. Because of this, conifers fragments are not represented in any of the following figures and descriptions.

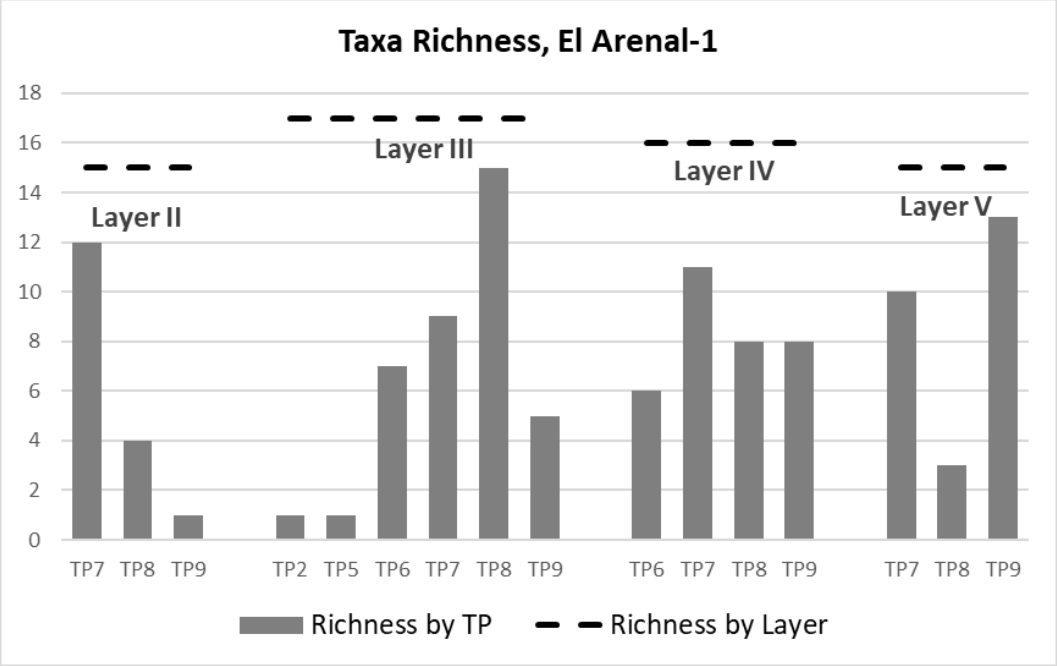


Figure 92: taxa richness in samples from El Arenal-1, according to layer and TP.

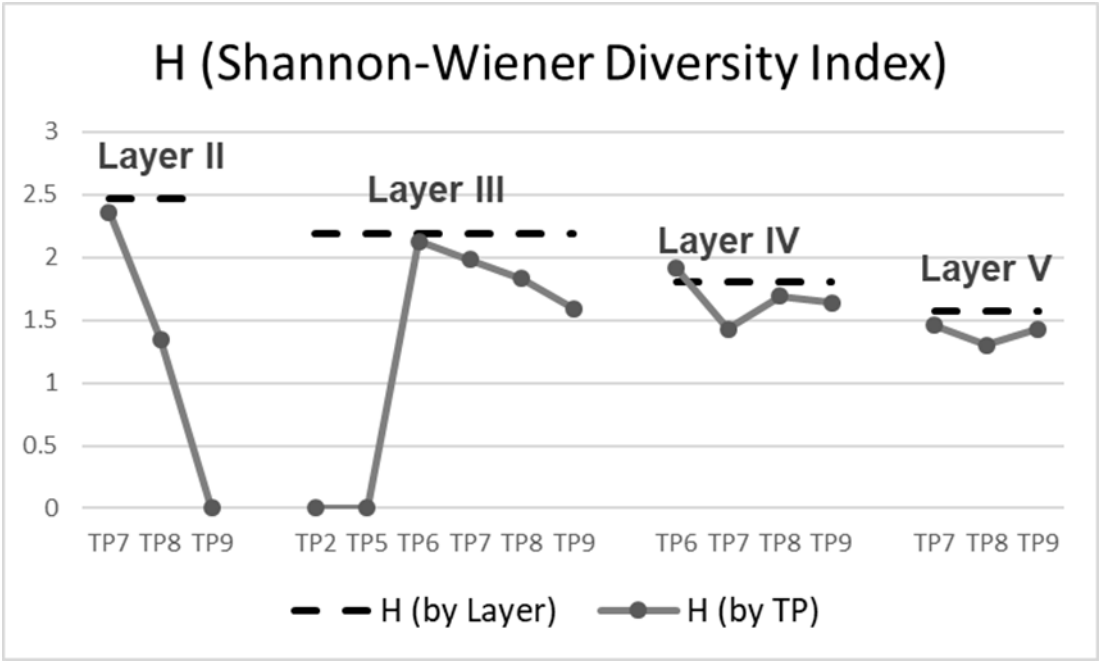


Figure 93: El Arenal-1 sample's diversity index.

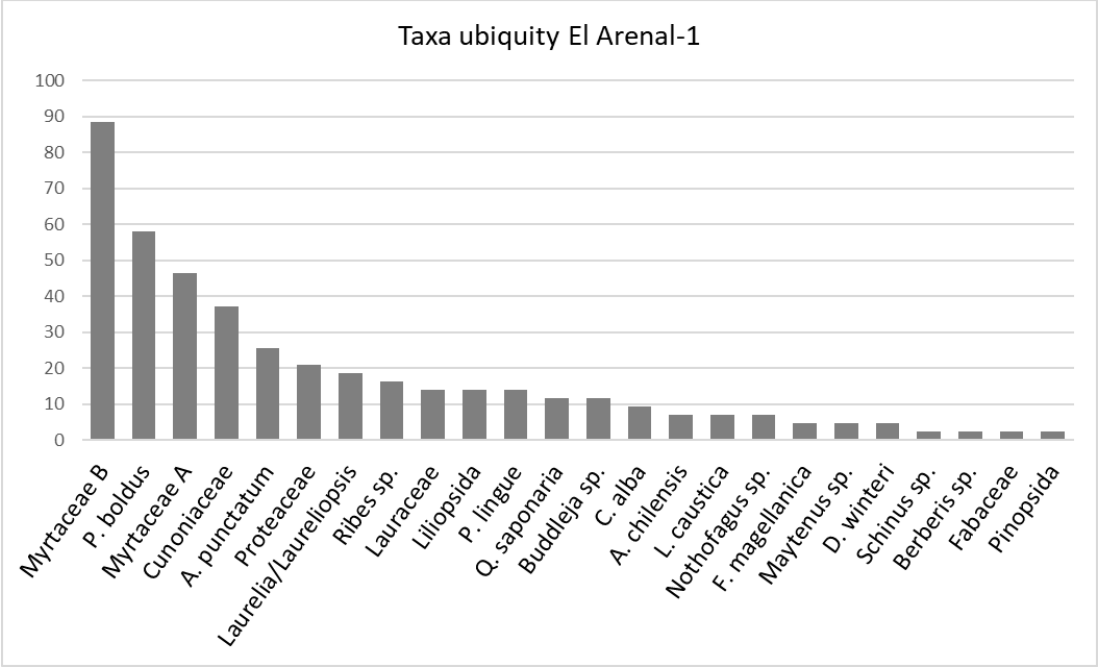


Figure 94: El Arenal-1 taxa ubiquity.

In terms of relative frequency and considering both excavation and flotation samples, there is a clear predominance of Myrtaceae type B in all layers but also in most of the TP (figure 95). Layer II of TP9 and Layer III of TP2 and TP5 are the only exceptions showing a predominance of other taxa, but in TP5 and TP9 is due to a small sample size. The case of TP2 is different because there is just one sample from this TP. Considering also the spatial distribution of the site, TP2 is further away from the rest of them, and the closest TP is TP4, which was quite different in relation to the identified taxa (Conifers were only registered in TP4). Although this could suggest differences contexts within the site, only one sample for TP2 and TP4 were analysed, so it not possible to make further interpretations.

Even though five different shrubs taxa were identified (*Berberis* sp., *Aristotelia chilensis*, *Ribes* sp., *Fuchsia magellanica*, and *Buddleja* sp.), they were all registered in low numbers. Altogether, they tend to represent values lower than 2%, except for the samples from Layer II in TP8, Layer III in TP5 and Layer IV in TP9.

Overall, most of the identified taxa were recognized in the different Layers, and not evident taxonomical differences were observed suggesting a sequential order of the layers (deeper vs superficial layers). This also has been supported by the dates of the site, suggesting a similar chronological frame for the four layers.

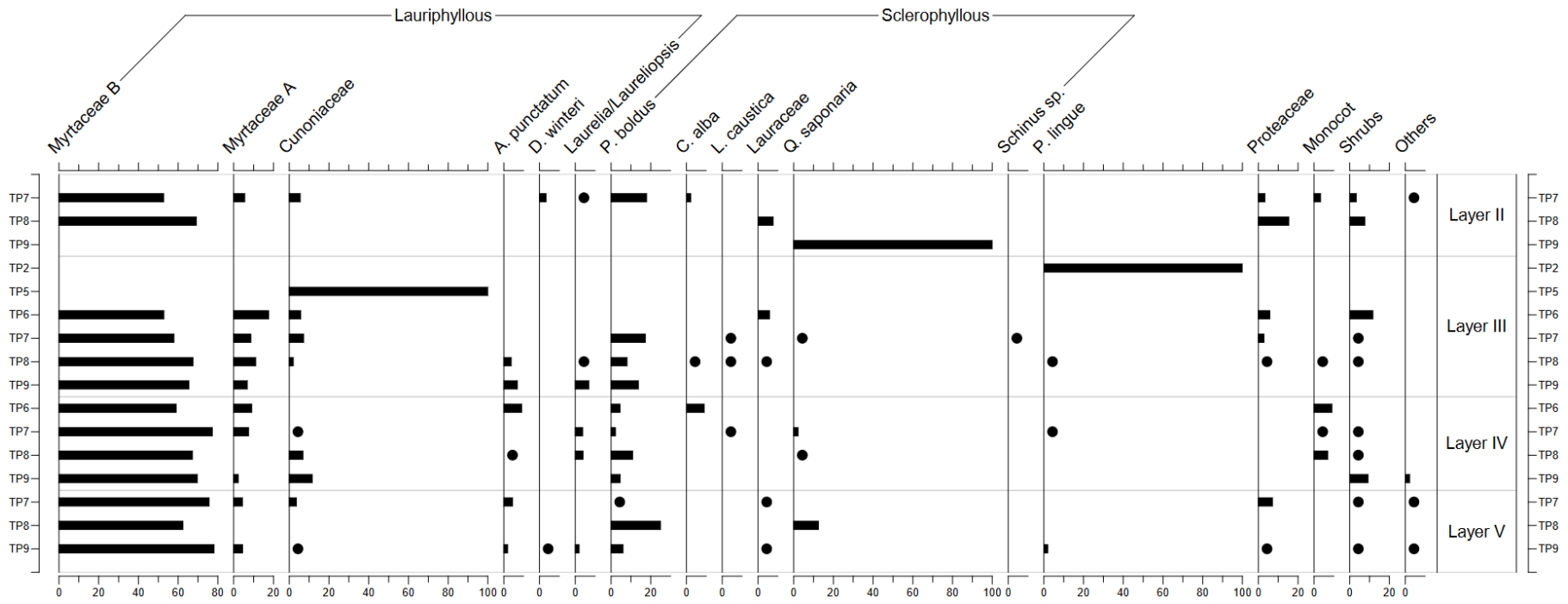


Figure 95: Relative frequency of identified taxa from El Arenal-1 according to Layer and TP. Circles represent values under 2%.

9.3.2 Unknown taxa

Among the 172 unknown angiosperm fragments, there was one type observed in different samples. This type was categorized as Unknown type B (description in Appendix B), and it was registered in five samples that correspond to Layer III to V (table 26).

Table 26: frequency unidentified types in El Arenal-1.

Unknown Fragments	Layer III		Layer IV	Layer V	
	TP6	TP8	TP8	TP7	TP9
Type B	1	4	1	1	6

9.3.3 Non-identifiable taxa

Among the 851 fragments categorized as non-identifiable, almost half correspond big size fragments (47.7%, over 4 mm). Most of the non-identifiable fragments were categorized as such because it was not possible to observe properly the tree anatomical plains (45%) or due to distortions associated to taphonomy processes (43.5%). There are many fragments presenting more than one type of alteration (shown separately in and in table 27), but the values in this written section represent the sum of each alteration

Almost half of all the non-identifiable fragments show one or more taphonomic features (45.6%). The alterations of wood growth were registered mainly as knots (7.1%), and other anatomical issues such as small diameter/gauge were observed less frequently (4.5%).

Table 27: Detail of non-identifiable fragments from El Arenal-1.

Non-identifiable fragments	Over 4 mm		4-2 mm		Total	
	N	%	N	%	N	%
Presence of one or more taphonomic features	227	26.7	143	16.8	**370**	**43.5**
Alterations related to wood growth	36	4.2	14	1.6	**50**	**5.9**
Small wood gauge (twigs)	15	1.8	15	1.8	**30**	**3.5**
Presence of alterations related to wood growth and one or more taphonomic features	8	0.9	2	0.2	**10**	**1.2**
Small wood gauge with presence of one or more taphonomic features	4	0.5	4	0.5	**8**	**0.9**
Not possible to observe all anatomical sections	116	13.6	267	31.4	**383**	**45**
Total	**406**	**47.7**	**445**	**52.3**	**851**	**100**

Considering the stratigraphy of the site, the higher percentage of non-identifiable fragments was registered in Layer II (58.5%), and the lowest in Layer III (31.9%). In the other Layers, the percentage is around 40%.

9.3.4 Alterations in the wood anatomy of the assemblage

In the samples from El Arenal-1, 68 fragments showed anatomical alterations registered as knots, mainly identified in fragments over 4 mm (73.5%). Most of the fragments showing knots were categorized as non-identifiable (88.2%), and only two identified taxa showed knots in small frequencies (table 28).

Table 28: wood charcoal from El Arenal-1 showing anatomical alterations.

Category		**Over 4 mm**		**4-2 mm**	
		N	**%**	**N**	**%**
Identified	Myrtaceae B	4	5.9		
	Peumus boldus			1	1.5
	Persea lingue	1	1.5		
Unknown		1	1.5	1	1.5
Non-identifiable		44	64.7	16	23.5
Total		**50**	**73.5**	**31**	**26.5**

9.3.5 Diameter measurements of the assemblage

Diameter estimations could not be conducted due to the fragmentation of the wood charcoal samples. Nevertheless, in 41 fragments it was possible to observe a complete diameter (less than 2 cm), indicating the preservation small gauge twigs in all the Layers. Most of the assemblage was categorize as non-identifiable: only one fragment categorized as unknown, and only one fragment was identified taxonomically as Myrtaceae A.

9.3.6 Taphonomy of the assemblage

A total of 500 fragments showed at least one taphonomic feature (figure 96), representing a 23.5% of the analysed wood charcoal fragments of El Arenal-1. If considered separately, the most frequent features registered was vitrification (n=420, 19.7% of the site's wood charcoal total), and in second radial cracks (n=50, 2.4%), both generally related to the combustion process. In less

frequency Infillings (1.9%), hyphae (1%), and structural collapse (0.8%) and xylophage insects were also registered.

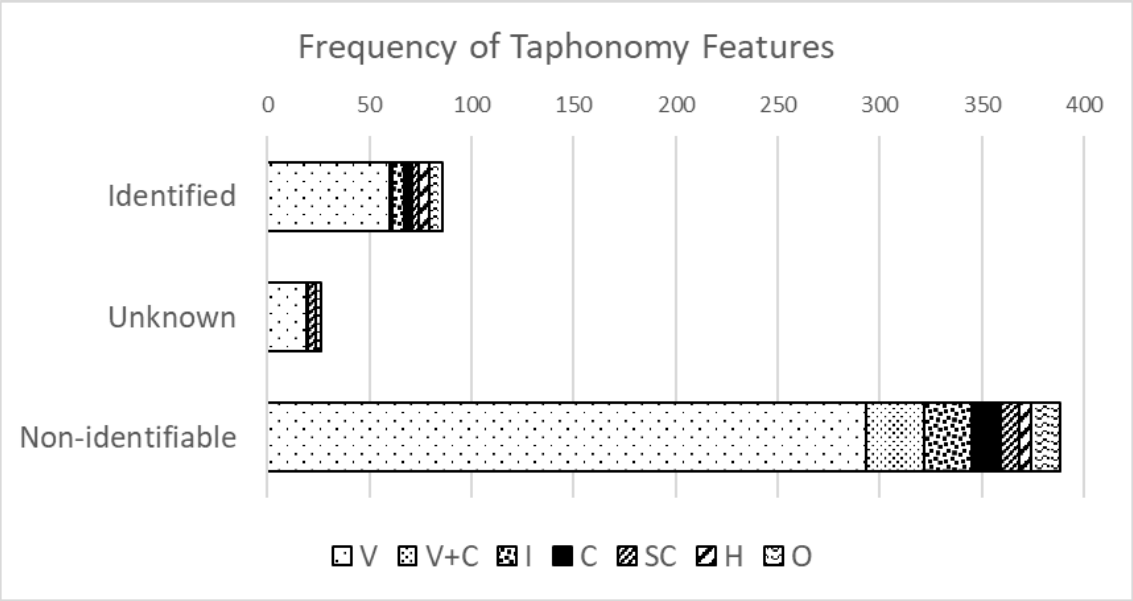


Figure 96: El Arenal-1 frequency of taphonomic features (V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse, and O: others).

Among the identified fragments, 7.8% showed at least one taphonomic feature, while in the unknown category it reached 3.1%. In terms of layers, the highest prevalence of taphonomic features is found in Layer II (32.9%), while in all the other represents around 20%. By also considering the TP, and if discarding small size samples, the highest percentage of taphonomic features is found in Layer II of TP7 (31%, figure 97).

Since a part of the fragments showed more than one taphonomic feature simultaneously (n=53), vitrification and radial cracks as the more frequent features, are presented separately from the rest (just to keep as simple as possible).

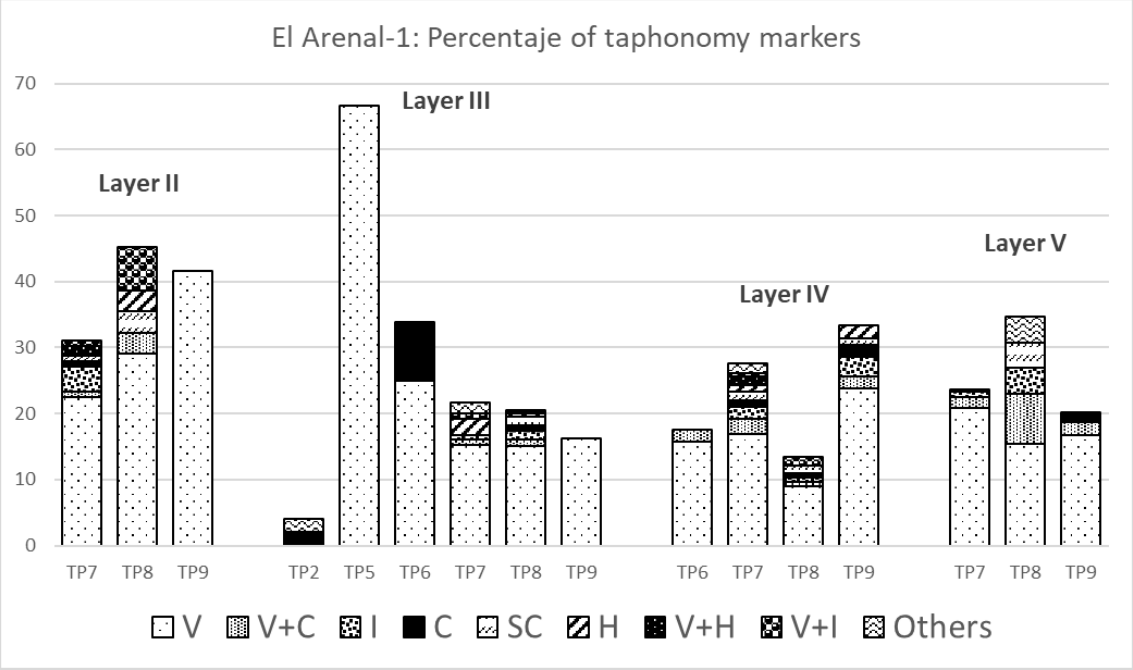


Figure 97: relative frequency of taphonomic features in El Arenal-1, according to Layer and TP (V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse, O: others).

Vitrification was registered mainly on its own (n=372, 17.5% of the site´s wood charcoal), and in less proportion along with radial cracks, hyphae, infillings, and other markers (figure 98, details in table 21, appendix A). Among the identified fragments, the most frequent taxa showing vitrification are the ones with a high frequency in the site´s wood charcoal assemblage like Myrtaceae type B and A, Cunoniaceae and *P. boldus*. Some of the other identified taxa showing vitrification belong to the Lauraceae family (*C. alba,* and *P. lingue*), and in lower frequencies *Nothofagus* sp. and *Ribes* sp. were also registered.

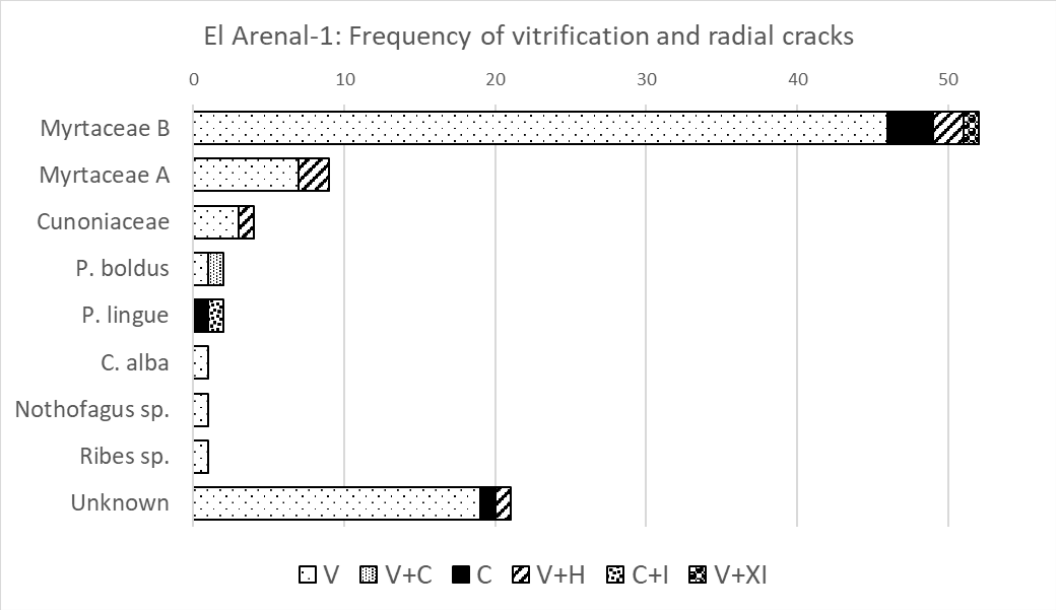


Figure 98: detail of vitrified fragments in El Arenal-1 (V: vitrification, C: radial cracks, H: hyphae, I: infillings, XI: xylophage insect).

Radial cracks were registered mostly along other markers and in less proportion on its own (1.6% and 0.9% respectively of the site´s wood charcoal). Among the identified fragments (figure 98), radial cracks were only registered in three taxa: Myrtaceae type B, *P. boldus*, and *P. lingue*.

Infillings were registered mostly on its own (figure 99), but also along other indicators (1.3% and 0.6 % respectively of the sites wood charcoal). The only identified taxa showing radial cracks are Myrtaceae type B, *P. Lingue*, and *P. boldus*. Structural collapse was registered more frequently on its own (0.7%), or along infillings and vitrification. Only two taxa showed structural collapse: *P. boldus* and Myrtaceae type A.

Hyphae were identified in similar proportions on its own and along other markers (1% of the site's wood charcoal total), and they were registered in four

taxa: Myrtaceae type A and B, Cunoniaceae and *Ribes sp.* There were only two fragment showing indicators of xylophage insects, one was identified as Myrtaceae type B and the other one as *P. boldus.*

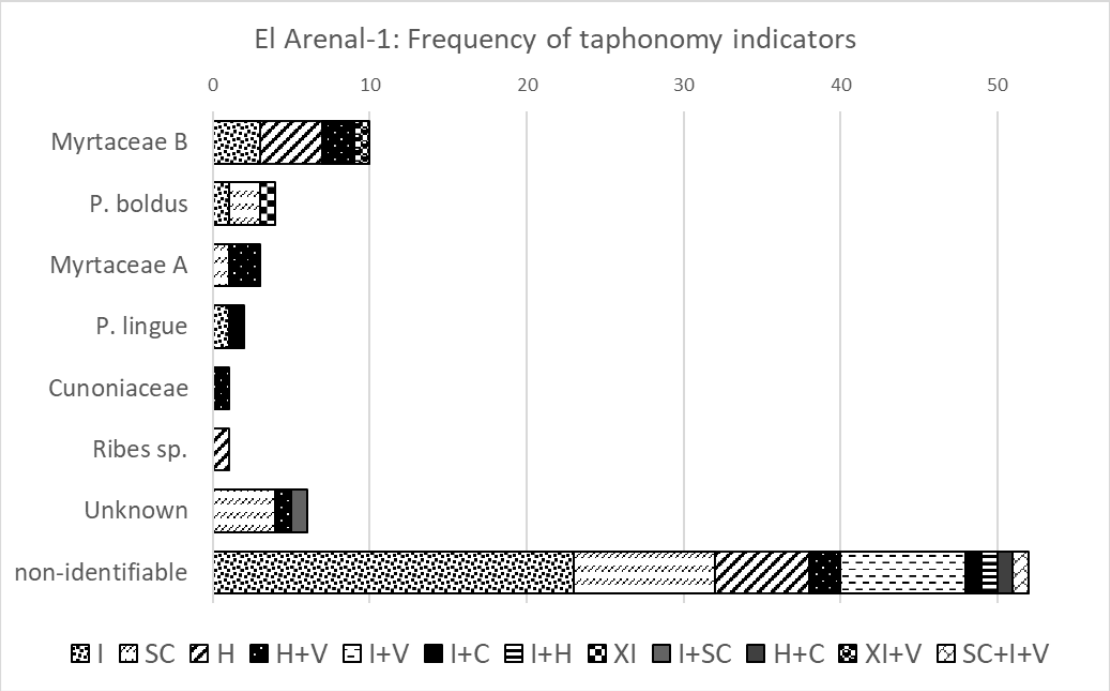


Figure 99: El Arenal-1Fragments with biological markers (H: hyphae, V: vitrification, C: radial cracks, SC: structural collapse, XI: xylophage insects).

9.4 Integration of the results with previous archaeobotanical information of the site

The previous archaeobotanical analysis of the site included charred seeds obtained from the same flotation samples described earlier (see detailed list in table 22, appendix A), from which the wood charcoal was analysed (Roa 2019). This means that the archaeobotanical information is concentrated in TP7 and TP9.

A total of 12 different taxa were identified among the recovered charred seeds, and similarly as observed in the wood charcoal record, the higher taxa richness was registered in Layer III and IV. Grasses, maize, quinoa and wild raspberry were identified in all the layers. Other economically important taxa such as *Aristotelia chilensis*, *Bromus* sp., cf. *Gaultheria*, and *Madia sativa* were registered in Layer III or Layer IV, and cf. *Fragaria chiloensis* was only registered in Layer II.

Considering also the information from the earlier excavation of the site, among the charred seed record there is a small representation of woody species. In the earlier excavations only *Cryptocarya alba* was identified, and in the 2018 excavations two woody taxa were reported: *Aristotelia chilensis* and cf. *Gaultheria* sp. Of the three, only cf. *Gaultheria* sp. (Ericaceae), was not identified among the wood charcoal assemblage. Considering the diversity of identified woody species, it seems highly probable that most of these taxa were available in the surroundings of the site. One of the possible explanations for the low representation of woody species among the charred seed record would

be a seasonal inhabitation of the site. Although it is unclear is whether the site was occupied during the entire year, because of its location, it could correspond to a site inhabited during the early spring of the southern hemisphere (September to December). According to the ethnographic information, fishing was traditionally conducted from September to April, but it is from September to December when most fruits and berries from woody plants are not yet developed (Godoy 2008).

Even though the zooarchaeological report from the 2018's excavations indicate not many fish remains, previous excavation results mentioned the importance of fish remains in the site, with a clear predominance of *Trachurus symmetricus* (Contreras *et al.* 2005). Another aspect to consider is the emergence of seasonal lagoons and wetlands, registered during the winter and spring months along the coastal areas of Southern Chile (Including the surroundings of El Arenal-1), to then disappear during the summer months. The ethnographic data indicates that seasonal lagoons and wetland were covered by grasses during the spring (like the different *Bromus* species and *Madia sativa*), which were exploited by the native indigenous groups (Aldunate 2005). The charred seed record from the site shows a clear focus on grasses and quinoa, agreeing with a seasonal inhabitation of the site. In addition, several archaeological sites have been identified in similar coastal environments with seasonal lagoons or wetlands in Southern Chile. This suggests a broad exploitation of these environments during the LCP, allowing the access to highly productive environments that combine marine resources with wet prairies and dunes (Sánchez 2005).

9.5 El Arenal-1 discussion of the wood charcoal assemblage

From an ecological perspective, the results indicate presence of lauriphyllous and sclerophyllous species, and in less percentage secondary shrubs (figure 100). For comparison purposes some species were grouped together under the family identification (Myrtaceae type A and B were grouped together as Myrtaceae, and *Lithrea caustica* and *Schinus* sp. were grouped under Anacardiaceae), and others under a broader category (*A. chilensis, F.magellanica, Ribes sp. Berberis sp. and Buddleja* sp. were grouped under shrubs). The taxa were classified according to their ecology and shade tolerance according to the published literature (Donoso 2006, Gutiérrez & Huth 2012, Luebert & Pliscoff 2006, Lusk & Del Pozo 2002, Lusk 1996, Rundel 1981). Most of the shrubs, monocots and some tree taxa (*P. lingue* and *Maytenus* sp.) show a broad ecological spectrum, being found in both forest associations, so they were not classified under sclerophyllous or lauriphyllous types. The Proteaceae and Fabaceae family were also not classified under those categories, because they both encompasses species with broad ecological distribution.

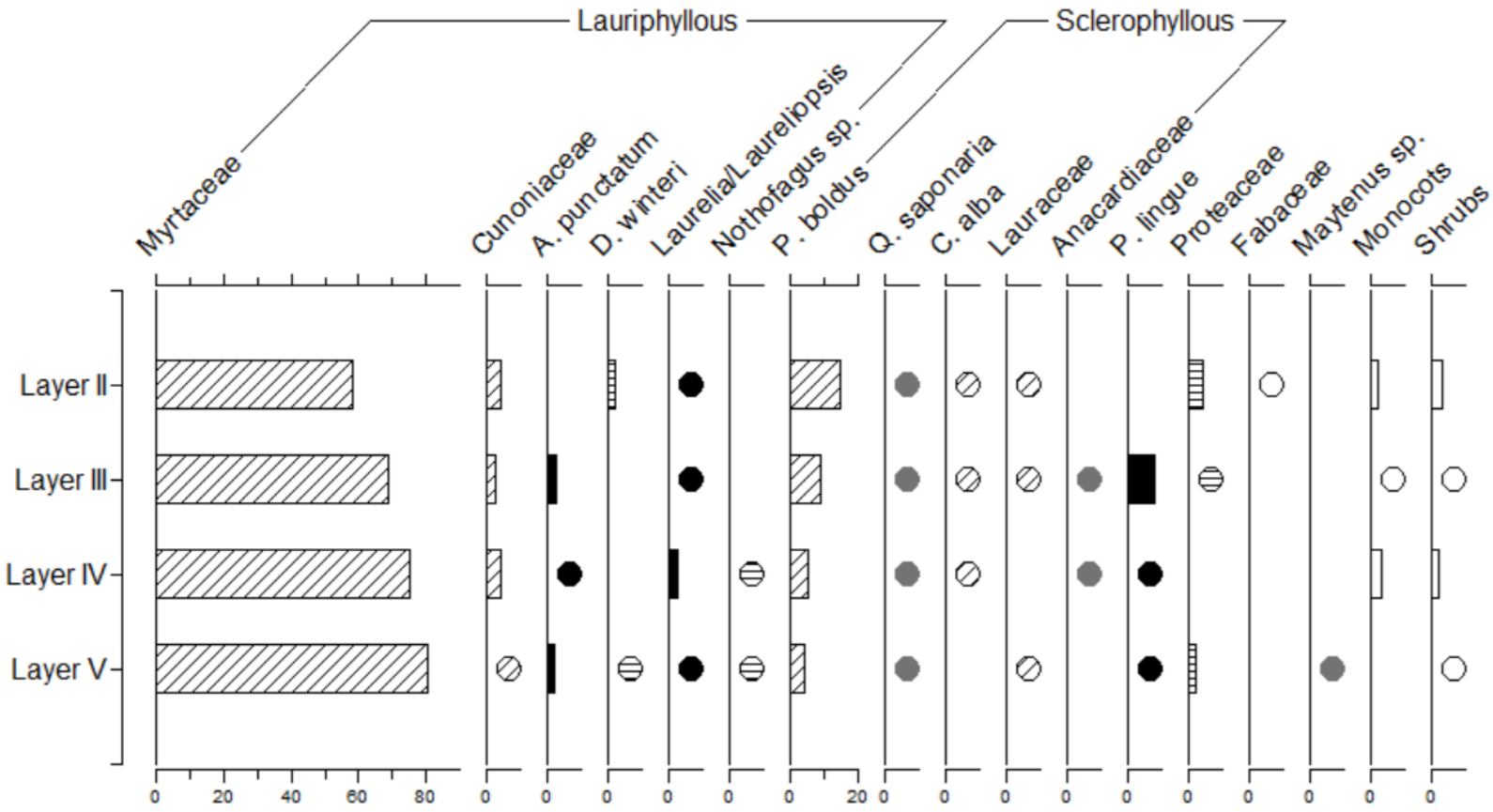


Figure 100: Summary of Identified Woody taxa from El Arenal-1 according to ecology. Black filling indicates shade tolerance; striped diagonal filling indicates shade tolerance to medium tolerance; striped horizontal filling indicates shade intolerance to medium tolerance; grey filling indicates shade intolerance. Unfilled or white colour indicates no specific shade/light tolerance. Circles indicate values under 2%.

In general terms, and as was mentioned in the previous result section, the layers are contemporaneous in chronological terms, so they cannot be interpreted as a temporal sequence. In terms of taxa richness, they are also similar, and in terms of diversity, the most superficial layers show higher index values than the deeper ones (figure 101).

In taxonomical terms, the lauriphyllous taxa dominates the site's wood assemblage (81%), while sclerophyllous taxa represent 9.3% and secondary shrubs only 2%. The shade tolerant taxa (*A. punctatum*, *Laurelia/Laureliopsis, and Persea lingue)***,** represent a 7.1% of the identified taxa, but if they are grouped with shade tolerant to medium tolerance taxa (Myrtaceae, Cunoniaceae, Lauraceae, *C. alba* and *P. boldus*), the representation reaches a 92%. At the other end of shade tolerance spectrum, we find three shade intolerant taxa (Anacardiaceae, *Q. saponaria* and *Maytenus* sp.) and three shade intolerants to medium tolerant taxa (*D. winteri*, *Nothofagus sp.* and Proteaceae*).* Altogether these shade intolerant to medium tolerance taxa represent just 3.7%.

Although there are not paleoenvironmental records near the site, the wood charcoal results contrast with the vegetation observed today in the nearby areas. Several coastal areas in the Biobío region have been affected by erosion related to the expansion of exotic forestry plantations and subsequent replacement of the native flora. One of the common invading shrubs widely distributed in Southern Chile is *Ulex sp*., which was present in the surroundings of the site and has been associated to the presence of nearby exotic forestry plantation (Gutiérrez *et al.* 2024).

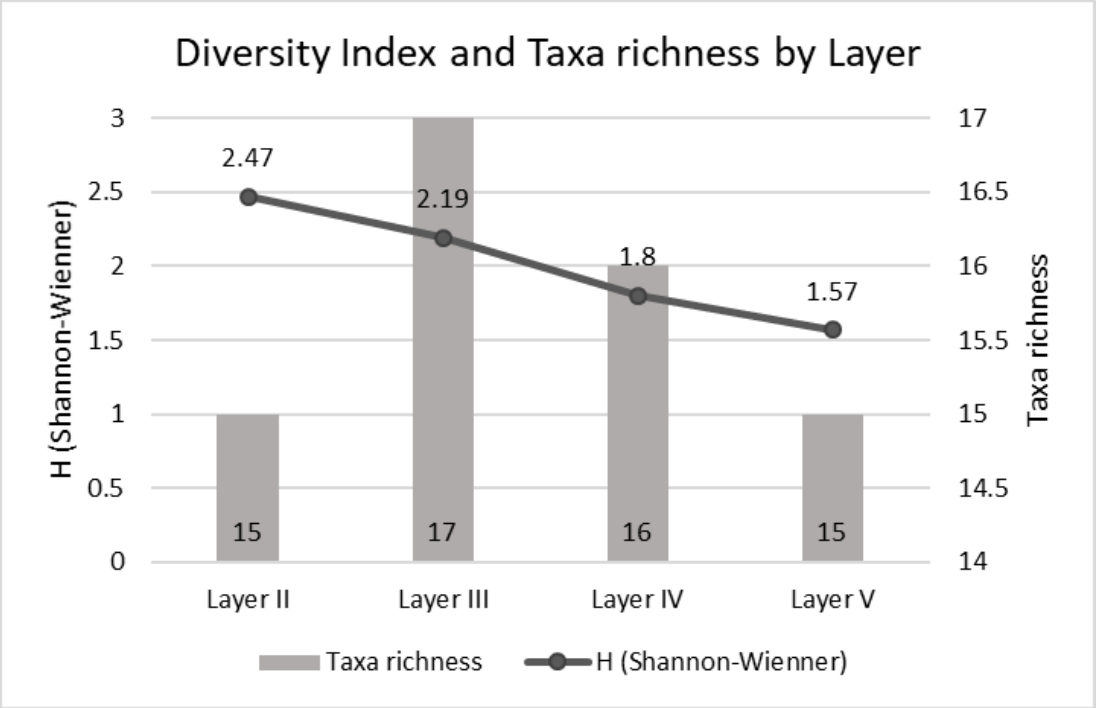


Figure 101: Relative frequency of charcoal identification categories in El Arenal-1 according to layer.

Altogether, the archaeobotanical data of the site indicates a Late Ceramic context with presence of wild and cultivated plants. As well as observed in other sites, along with these cultivated taxa (quinoa and maize in this site), there is also an ubiquitous representation of berries *(Rubus* sp., *A. chilensis,* and cf. *Fragaria chiloensis).* Since no wood charcoal samples were analysed in the previous excavation of the site and few woody taxa were represented in the charred seed record, the recent excavation contributed significantly to expand the range of vegetal resources used in the site.

9.6 Summary of results and interpretations from El Arenal-1

In terms of chronology, the site shows an inhabitation between the beginning 14th and 15th centuries. Because it was not possible to establish a finer chronological adscription of the different archaeological layers, the whole wood charcoal assemblage was ascribed to the Late Ceramic Period.

A sum of 24 native woody taxa were identified, including trees, shrubs and other minor wood like plants (monocots). The most frequent and ubiquitous taxon is Myrtaceae type B, and although among the identified species there are lauriphyllous and sclerophyllous types, there is clear a predominance of the lauriphyllous type.

The identified taxa indicate a predominance of shade tolerant to semi tolerant families and species. Unlike the previous sites, charred seed from woody taxa were barely recovered, suggesting a possible seasonal inhabitation of the site during months when there are not available fruits (winter to early summer).

Chapter 10: Discussion, conclusions and further comments

10.1 Integration of the results, the wood charcoal record and the forest during the pre-Hispanic and Historical Period in Southern Chile

Considering the wood charcoal from all the sites included in this dissertation, a total 38 different taxa were recognized. Although most of the taxa was primarily used as firewood, 36 of them have other traditional ethnographic uses (details in table 23, appendix A). Among the identified taxa, 24 of them have reported edible parts (from fruits and seeds, to shoots, leaves and even bark), 15 have reported medicinal properties, and eight can be used as dyes.

Because each of the sites have their own archaeological, ecological and geographical context, but also different chronologies, the integration and discussion will be divided into three main interpretative axes. From the most specific to the broader topics, first to be discussed are the particularities of each the sites, then the similarities and differences in relation to their ecological and geographical settings, and at last, the chronological trends observed during the pre-Hispanic and Historic Periods.

10.1.1 Particularities at site level

Different issues were noticed in relation to the analysis and interpretation of the wood charcoal assemblage, starting with the fact that different teams excavated the sites so there was not a standard criterion in relation to the sampling processes. Another aspect to consider is that most archaeological

excavations in Southern Chile have followed a test pit grid methodology. This type of site assessment allowed the sampling and statistical comparison of the sites (Campbell 2020), but it does not provide detailed contexts or inform about different activity areas within the sites. Related to this, while most of the archaeological sites considered in this dissertation have been classified as habitational or domestic sites, it is uncertain how they were inhabited (all year-round, seasonally, or sporadically).

Because of the insular isolation, the analysed Mocha Island sites presumably represent a permanent occupation during the LCP (all year-long). For Cueva de los Catalanes and El Arenal-1, it is not clear how regularly and for how long each time were the sites inhabited, and seasonality has not been addressed among the archaeological analyses. For El Arenal-1, the different lines of evidence suggest an inhabitation during the winter months to early summer. The archaeobotanical record also suggest a seasonal occupation, but considering the small volume of sediment floated, further analysis directed towards seasonality should be implemented.

In Cueva de los Catalanes, the current data informs that the cave was used more recurrently during the ECP, and less frequently in the LCP and HP. But the character of the occupations is still unknown. Another relevant aspect in this site is that because of its cave condition, it was initially interpreted as a ritual place. Besides form the rock art there is no evidence supporting proper ceremonial activities that differ from daily chores like food preparation and consumption or keeping hearths. Nevertheless, no proper analysis has been conducted towards the possible ritual aspect of the site,

starting with a detailed comparison with other sites in order to identify different types of activities (like food offerings).

Another difference among the sites is the specific depositional context. Although the Mocha Island sites and El Arenal-1 are all located less than 1 km away from the shoreline and they correspond to open-air sites, the sediments and postdepositional process are different. In Mocha Island the disturbance was associated with recent farming (last hundreds of years), affecting the more superficial layers of the site (average of first 40 cm), but there was a hight prevalence of taphonomic features in the medium depth section of the sites (between the 65-75 cm in P5 and Layer III in P29). In El Arenal-1, the most superficial layer (LII) shows the highest prevalence of taphonomic features, probably related to the active transport of sands from the dunes. In Los Catalanes cave there is a completely different depositional environment, and the highest prevalence of taphonomic features were registered in the deeper layers (corresponding to the ECP). In the Mocha Island sites and the Catalanes cave, the layers with high taphonomic rates were related to the recurrent use of the space and with a probable disturbance of the sediments (the preparation of floors, or cleaning activities). In El-Arenal, the taphonomy was related to environmental conditions, rather than the occupation's dynamics of the systemic archaeological context.

Keeping in mind these differences, we also noticed similarities between the sites. In all the sites, more than 20 taxa were identified representing trees but also shrubs and other minor woody like plants. This indicates a diverse availability of woody species around the different sites, but also indicates

that wood gathering practices do not necessarily show preference of certain taxa over others.

This taxa richness is related to the type of analysed samples, since scattered charcoal dispersed in archaeological sediments tends to represent more taxa than a concentrated feature like a hearth. Although some “feature” samples were also included in the analysis, because of the excavation methodologies, it is unclear if these samples correspond to refuse areas, or primary fireplaces. Also, these analysed feature samples did not represent the integrity of the features (only sub samples were taken during fieldwork), which is not ideal in sampling terms (Théry-Parisot, Chabal & Chrzavzez 2010).

10.1.2 Geographical and ecological differences among the analysed sites

Three main different settings were represented in this dissertation: an Island, a continental coastal area, and the longitudinal valley. In ecological terms they are all located in an area of vegetal transition between the sclerophyllous and lauriphyllous forests, and the wood charcoal data sets represent that. Overall, there is a predominance of lauriphyllous taxa in all of the analysed sites, but even in lower percentages, sclerophyllous taxa are always present in the different periods.

In all the analysed sites the most frequently identified taxa were the Myrtaceae family, while the Myrtaceae type A was the predominant in the Catalanes Cave and Mocha Island sites, the Myrtaceae type B was the most common taxon in El Arenal-1. The closer sites in the Puren-Lumaco Valley

with wood charcoal data sets also show a relevant percentage of Myrtaceae, although these sites have a small number of analysed fragments (Solari 2014). Further south, in the Marifilo-1 rock shelter site, wood charcoal from the Myrtaceae family were frequently registered but not in a high proportion as in the sites here discussed (Lehnebach *et al.* 2008). One of the taxa frequently reported in other wood charcoal analysis in Southern Chile is *Nothofagus sp*. (Lehnebach *et al.* 2008, Mera & Munita 2021, Solari 2014, Soria-Galvarro 2022), which in this analysis was only registered in a relevant percentage in Cueva de los Catalanes. While sclerophyllous taxa were frequently registered among the analysed sites for this dissertation, they are not reported in the other sites with wood charcoal data. The only sclerophyllous taxon found frequently in most sites is *Peumus boldus*, wich as well as *Persea lingue*, are commonly found among sclerophyllous but also lauriphyllous associations (Rodriguez, Matthei & Quezada 1983) . Overall, these differences among the wood charcoal data sets from each site reflect forest associations with a clear north to south gradient.

Another relevant aspect to highlight is the low representation of conifers, not only in the analysed sites for this dissertation, but also in the other documented sites of Southern Chile. Although the angiosperms are dominant in the South American Temperate Forests (Armesto, León & Kalin 1996), this could be also related to the longitudinal location of the archaeological sites. There is no much charcoal data available from higher altitudes or from proper mountain ranges sites, where the conifers predominate (Armesto *et al.* 1995).

Considering altogether the analysed sites, there are nine taxa registered in all them: *A. punctatum, Maytenus sp., Cunoniaceae, A. chilensis, Ribes sp., Laurelia/Laureliopsis, P. boldus*, Myrtaceae type A, and *Buddleja* sp. Five of them correspond to trees, and in all of the sites, trees tend to dominate the anthracological spectrum. The sites where non-tree taxa such as shrubs represented a significant portion of the wood charcoal assemblage were the sites from Mocha Island. In ecological terms, most of the identified shrubs correspond to secondary formation typical of the forest succession of Southern Chile, so their presence in the wood charcoal record informs of disturbance, usually associated with fire. Because of the insular condition, the presence of secondary shrubs could be related to an increasing demand over the island resources (burning of shrubs after a shifting cultivation cycle), especially in relation to the population growth during the LCP. Nevertheless, is important to keep in mind that the analysed Mocha Island sites are the only ones representing an all-year occupation, so the wood charcoal samples correspond to recurrent wood fire collection around the domestic units.

The low percentages of shrubby taxa in Cueva de Los Catalanes and El Arenal-1 site do not necessarily mean a less disturbed environment, especially considering that they could represent seasonal procurement of wood fire, or even a sporadic one.

At the moment, there is not comparable data from domestic sites with a permanent inhabitation in the mainland to contrast with the Mocha Island sites. Preliminary, the differences observed in relation to the percentages of shrubby species could respond to the different inhabitation dynamics of the

sites, rather than represent differences related to geographical conditions (island versus continental contexts).

Considering the shade tolerance or intolerance of the different taxa identified in the sites, in the Mocha Island sites and El Arenal-1 there is a clear predominance of shade tolerant to medium tolerant taxa (between 67% to 90% in different periods and sites). Cueva de Los Catalanes shows a more equilibrated panorama in the pre-Hispanic Periods, when both shade intolerant to shade tolerant species represent each around 40%. At first, this could be interpreted as differential disturbance patterns between coastal areas (Arenal-1 and Mocha Island) and the longitudinal central valleys (Cueva de los Catalanes). According to the environmental history, the coastal zones were deforested more recently than the central longitudinal valley (Camus 2005, González-Marilicán 2020), suggesting a higher conservation of old-growth forest in the coastal area. The expansion of the deciduous *Nothofagus* in the central longitudinal valleys has been used as an indicator of recurrent fire disturbance, which according to some authors dates back from pre-Hispanic times (Otero 2006). Another important geographical fact to be kept in mind in Cueva de Los Catalanes, is the proximity of the Vergara River (less than 1 km away). At least during the LCP the native populations were allegedly concentrated around river basin because of their cultivation needs. The high representation of shade intolerant species in Los Catalanes cave might then reflect an environment with open areas, clear of dense forest or closed canopy, where shade intolerant species can regenerate and develop. The identification of *Nothofagu*s sp. in all the periods of the cave is congruent with this

interpretation, as well as the identification of *Salix* sp. in the LCP and HP (pioneer taxon in water-saturated environments like riverbanks).

10.1.3 Archaeological Periods and the wood charcoal data from Southern Chile

There are seven sites with published wood charcoal information in Southern Chile (figure 102), and even though Mocha Island and the Purén-Lumaco valley concentrate more than one site, they are counted as one each. Of them, only Marifilo-1 provides a pre-ceramic component (details in table 24, Appendix A). This shows a concentration of data in the Ceramic Period (particularly in the LCP and the HP), which reflects the objectives and focus of recent archaeological projects in the region. Also, since most of the sites were excavated in different years, (and by different archaeological teams), the samples from the different sites are not directly comparable. Considering these limitations, the incorporation of wood charcoal data from other sites will be mostly in terms of taxa presence and absence.

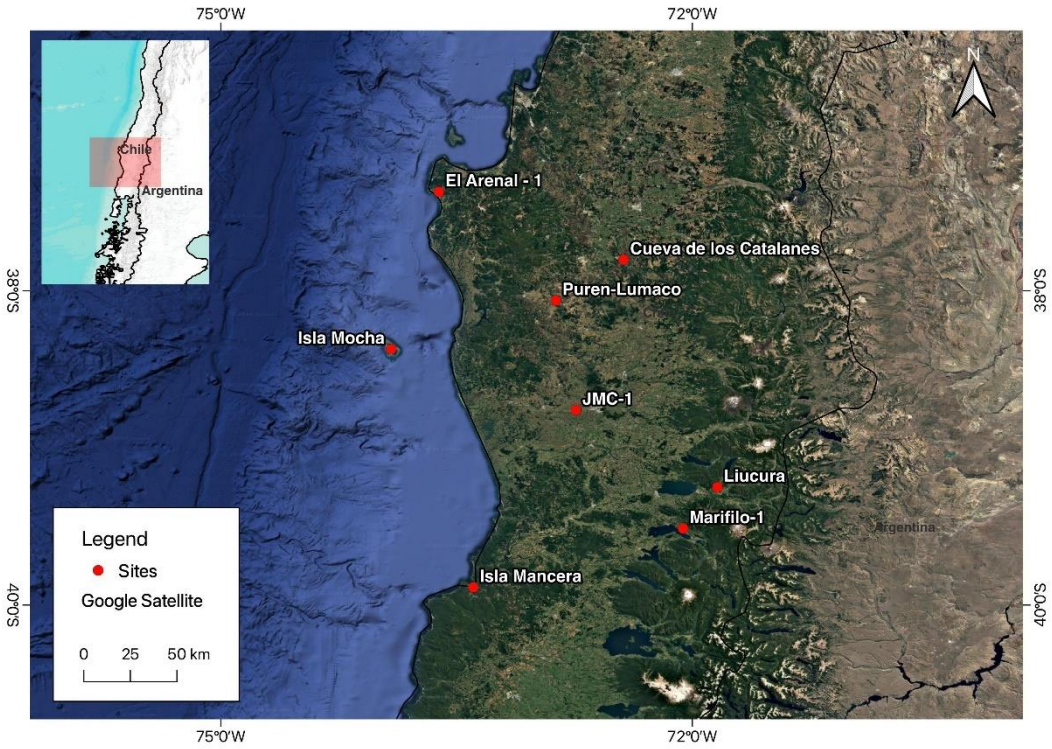


Figure 102: Map showing the location of archaeological sites with wood charcoal in Southern Chile.

For the pre-ceramic Archaic period there are two chronological phases represented in Marifilo-1 rock shelter, an Early Holocene one (dated around the 6000 BCE / 8000 BP) and a Mid-Holocene phase (dated around the 4000 to 3000 BCE / 6000 to 5000 BP). The dispersed wood charcoal recovered in the Pre-ceramic layers informs of eight taxa for the early Holocene and 22 in the mid-Holocene (Lehnebach *et al.* 2008). In the early Holocene, *Persea lingue* and *Aristotelia chilensis* are the most common taxa, and later in the Mid-Holocene, *Peumus boldus*, Myrtaceae, Monocots and *Nothofagus* sp. are the most commonly identified ones. The authors suggest that the identified taxa correlate to the paleoclimatic records that show drier and warmer conditions during the early and mid-Holocene, with is a clear predominance of thermophilus vegetation (Abarzúa *et al.* 2014).

There are only two sites with wood charcoal data for the ECP, Cueva de los Catalanes (deepest layers, 550-1200 cal. CE) and Villa JMC-1 (around 800-1200 CE). The Villa JMC-1 site is a cemetery with almost 50 identified individuals (Mera & Munita 2021), and most of the charcoal was recovered in small features in association with human skeletons, interpreted as possible ritual fires. Among the ten identified taxa, the predominant ones were *Nothofagus* sp. and *Aextoxicon punctatum*. Most of the taxa identified in Villa JMC-1 were also identified in the ECP of Cueva de los Catalanes. The only taxon missing in Los Catalanes Cave is *A. punctatum*, and in terms of frequency the cave shows a predominance of the Myrtaceae family (types A and B), and *Drimys winteri*. Even though the archaeological context of both sites is different (burial versus habitation site), they are both located in the longitudinal valley in places near water streams (Villa JMC-1 is 300 meters away from the Botrolhue stream and 1.5 km away from the Cautín River). Ecologically, it is possible that a similar type of vegetation surrounded both sites, and even tough a limited number of taxa was identified in the wood charcoal assemblage from Villa JMC-1, among the charred seeds other woody species were identified, including Myrtaceae, *D. wintery* and *C. alba*, all corresponding to taxa also identified in Cueva de los Catalanes.

For the LCP there are six sites representing different contexts and environmental settings. In the coastal sites of Isla Mocha and El Arenal-1 there is a clear predominance of the Myrtaceae family, with predominance of lauriphyllous and shade tolerant taxa. In the central longitudinal valley, there is data from the Purén-Lumaco valley that includes ceremonial sites (mounds or *Kuel* sites) and domestic sites (Solari 2014). Among the *Kuel*

samples, there is a predominance of *Nothofagus* sp., with few other identified species like *Aextoxicon punctatum*, *Aristotelia chilensis* and the Proteaceae family. In the domestic contexts there is a predominance of Myrtaceae family, and the other identified taxa are *Nothofagus* sp., *Persea lingue, A. chilensis, A. punctatum*, and Proteaceae. Although the samples are not comparable, the wood charcoal from the Purén-Lumaco Valley shows species identified in Cueva de los Catalanes. In general terms, the LCP samples from Los Catalanes cave show a diversity not represented in the Purén-Lumaco Valley, which is probably due to the different types of sampling used in each site, and the number of analysed fragments. Nevertheless, the Purén-Lumaco data supports the evidence obtained in the Catalanes Cave, where a predominance of Myrtaceae is observed, along an important representation of shade-intolerant to medium tolerant taxa such as the *Nothofagus* genus.

In the piedmont area or the *precordillera*, there are two sites with charcoal evidence for the LCP. The first one corresponds to the Liucura Valley, where samples were taken from a ceremonial context of *Kuel* (Dillehay 2010). Six taxa were identified in these contexts, including *Nothofagus* sp., A. *punctatum, A. chilensis, Persea lingue, Chusquea* sp. and unidentified vines (Solari 2014). Further south but also in the piedmont zone, in the Marifilo-1 rock shelter 20 taxa were identified, being the most frequent ones *Aextoxicon punctatum, Nothofagus sp*., the Proteaceae family and *A. chilensis* (Lehnebach et al. 2008).

Finally, for the HP there is data from Cueva de los Catalanes, Millahuillin-1, and Isla Mancera, the last two located farther south in Los Rios Region. In

chronological terms, Millahuillín-1 (15th to 18th centuries) and Cueva de los Catalanes (16th to 18th centuries), date to early post-contact years, while Isla Mancera dates from the 17th to 19th centuries (some contexts are post-1760 CE, Soria-Galvarro 2022). Millahuillín-1 corresponds to a burial context with little published data (Solari 2016), where remains of a possible "*entierro en wampo*" (wooden raft burial) were recovered and identified as *Nothofagus* sp. Isla Mancera, is an island located in the mouth of the Valdivia River, where remains of a fortified "castle" are still visible. Unlike most of the other sites mentioned in this section, the samples from Isla Mancera cover different areas and structures (like the church, garden, house, main square and others), and the wood charcoal analysis informs of more than 20 taxa with a predominance of the *Nothofagus* genus and *Laurelia* sp. (the Laurelia genus used to have two species*, L. sempervirens* and *L. philippiana*, and although they are now under different genera, they are included in this discussion under the nomenclature used in their original publications). Although in less proportion, sclerophyllous taxa were also reported in this site, like the *Schinus* genus (Soria-Galvarro 2022). Even though specimens of the Myrtaceae family were registered in Mancera Island, they are not as predominant as in Cueva de los Catalanes.

This data compilation shows that the general wood charcoal data for southern Chile is still fragmentary. For the Archaic pre-ceramic Periods, the only data comes from the piedmont (Marifilo-1), and although the wood charcoal shows a correlation with the environmental paleorecords, there are no more data sets in Southern Chile to compare. Farther south, in the northern Patagonian Chanels (Reloncaví gulf and Chiloé archipelago), there is data from Archaic marine hunter-gatherer sites like Piedra Azul-

1(Gaete et al. 2004), Puente Quilo (Sierralta Navarro *et al.* 2024), and Chepu-05 (Rebolledo *et al.* 2021). All of these sites correspond to coastal open-air context where fragments from the Myrtaceae family were recovered along other species, but since they are from different ecological and cultural contexts, they are not comparable (details in figure 6 and table 2).

During the ECP the available data comes from the central longitudinal valley of the Araucanía Region (Cueva de los Catalanes and Villa JMC-1). In both sites there are lauriphyllous taxa (like *Aextoxicon punctatum),* as well as *Nothofagus* sp.

For the LCP, the coastal sites of Mocha Island and El Arenal-1 show a clear predominance of Myrtaceae, while in longitudinal valley there is also a relevant percentage of Myrtaceae along with the *Nothofagus* genus. In the precordillera or piedmont, *Aextoxicon punctatum* and the *Nothofagus* genus are the predominant taxa. Altogether, the LCP wood charcoal assemblages show the highest taxa richness, this can be due to the higher number of samples and sites, rather than just reflecting a diversified use of woody taxa.

Finally, the data for the HP shows predominance of Myrtaceae and *Nothofagus sp.* in the central longitudinal valley, and in the coastal area from Los Rios Region there is a predominance of *Nothofagus* sp., and other lauriphyllous taxa such as *A. punctatum* and *Laurelia* sp.

In general terms, the Myrtaceae family predominates in the more northern contexts of southern Chile (until the 38°S), while *Nothofagus* and *A. puctatum* are more frequent in the Southern sites (38°-40°). Similarly, most

of the sclerophyllous taxa were found in the northern zone of Southern Chile, which makes sense in a north to south geographical gradient. Previous studies have proposed an apparent bond between the deciduous *Nothofagus* forest, archaeological sites and ecotone habitats, which provided more open spaces where resources were abundant (Solari 2008).

Another important fact is that in all the contexts, secondary taxa indicative of forest succession were identified, being the most ubiquitous *Aristotelia chilensis.* In none of the analysed and review sites there is evidence to support the existence of an old growth forest, more likely, the identified taxa represent an intermediate stage where different shade tolerant and intolerant species can coexist. Considering also that in the analysed sites sclerophyllous taxa was always identified, it is possible to suggest that during the pre-Hispanic Ceramic Period the groups who inhabited southern Chile were probably promoting ecotonal areas.

In the only site with a complete sequence from the pre-Hispanic ceramic Periods to the HP is Cueva de los Catalanes. In this site we observe a continuous decrease of taxa from the sclerophyllous forest including some late successional species like *Peumus boldus*, *Cryptocarya alba*, and *P. lingue* (although this last taxon can also be found as part of the lauriphyllous formations). The most frequent taxa in the site like Myrtaceae and *Nothofagus* sp. can be associated with early and medium stages of the forest succession, and their increase over time suggests a possible regeneration of the lauriphyllous forest. This could be related to the less intensive use of the cave during the LCP and HP, especially if we consider that after the Spanish arrival, part of the native population moved from the

central valleys to more secluded areas protected by the vegetation. So, even though the Catalanes cave shows a more open landscape in comparison to the wood charcoal record of Mocha Island or El-Arenal-1, there is an increase of early to intermediate successional taxa since the LCP to the HP.

As an overall interpretation, I propose that if there was ever a pristine forest in Southern Chile, probably it started to be clear and burned by people earlier than the ECP (approximately earlier than the 500 CE).

10.2 Conclusions

From the revision of early Historic written sources and considering all the limitations and biases of the early eyewitnesses, it is clear that Southern Chile was far from being a virgin forest during the early decades of the Spanish conquest. The descriptions of cultivated fields along with *caseríos* or areas with a concentration of domestic units agrees with the archaeological record of the period preceding the Spanish Conquest, the Late Ceramic Period (1000-1550 CE). The archaeobotanical record provides direct evidence of cultivated plants, and the archaeological sites show a recurrent use of the space around domestic areas.

The wood charcoal results obtained as part of the analysis of this dissertation indicates that since the Early Ceramic Period (from 200/400 CE), people were using and burning different woody species of the temperate forest. In ecological terms, the results show the presence of lauriphyllous and sclerophyllous taxa, as well as shade tolerant and shade intolerant taxa, the latter from clearings or forest margins.

In chronological terms, most of the evidence was obtained from sites and layers within the sites ascribed to the Late Ceramic Period that also continued into the early centuries of the Historic Period. Nevertheless, none of these sites show a consistent and continuous inhabitation during the Historic Period, which is related to the conquest war in Southern Chile. In the case of Mocha Island, the forced eviction of the indigenous population was a direct intervention of the Spanish authorities. But in the other cases, due to the decimation of the population and territorial changes after the foundation of Spanish cities and forts, several previously frequented or

inhabited areas were abandoned (which could have been the case for El Arenal-1 site), or used sporadically (which could have been the case for Cueva de los Catalanes).

From the Historic sources and written testimonies, it is possible to observe two situations. Between the Biobío and Toltén Rivers (36°49'S to 38°60'S), there references of open lands as well as forest areas. South of the Toltén River, the descriptions from the 19^{h} century usually emphasize the wilderness of the territory and its abundant vegetation. Although both zones correspond to Southern Chile, they have ecological and historic differences. In broad terms, the more northern zone of Southern Chile is classified as a transition between the Mediterranean and Temperate zone, and the southern part corresponds to the Temperate macrobioclimatic unit (Luebert & Pliscoff 2006). This means that sclerophyllous species coexist with lauriphyllous taxa in the northern zone, unlike the southern areas dominated by the Valdivian rainforest. Because of these ecological differences, the forest regeneration also occurs differently, since for some late successional sclerophyllous taxa it is hard to recolonize disturbed areas (Armesto & Pickett 1985). In cultural and historical terms, the archaeological knowledge suggests that the settlement pattern and subsistence strategies characteristic of Late Ceramic Groups (mostly referring to *El Vergel* cultural complex), involving agriculture and management of camelids, was restricted to the northern zone of southern Chile. Also, most of the mound and platform complex have been reported for this northern territory, more specifically around the Purén-Lumaco Valley (Dillehay 2007). This means that in comparison, the northern zone of Southern Chile was probably more densely populated by agricultural groups since 1000 CE. This territory was

later declared as the Free Indian Country (1604 CE – 1825 CE), which suggests major continuities in the use of space by indigenous groups than what can be expected South of the Toltén River, where Spanish settlements were concentrated around Valdivia, Osorno and Chiloé.

Because of these differences, it could be argued that the forest of the more northern zone of Southern Chile (between the Biobío River and the Toltén River 36°49'S to 38°60'S), has been shaped since pre-Hispanic times more intensively than the southern portion. As a result, the "park like" vegetal formations described for the area between the Malleco and Cautín Rivers (37°44'S - 38°45'S) persisted until the 20th century (Fuenzalida & Pisano 1965). In contrast, the references south of the Toltén River, mentioned a more vegetated landscape probably reflecting centuries of forest regeneration. Since the current archaeological and archaeobotanical data is concentrated in the northern zone of Southern Chile, is necessary to include samples from the southern zone in order to evaluate this situation properly. At the same time, it is necessary to study a broader chronological and geographical context representative of the southern Chile region, including the cordillera and other unrepresented areas. The results of this study are an initial approach, and even though there are some difficulties and limitations that need to be addressed, they show the potential of wood charcoal analysis, as well as the rich information available from early written accounts.

Among the limitations, it seems important to address the concept of old growth forest. In ecological terms, I was under the impression that since the succession dynamics and responses to disturbance of the temperate forests

of South America were well studied, it was possible from a taxonomic perspective to use certain taxa as indicators of environmental conditions, fire effects, successional events, and late successional events (Donoso *et al.* 2015). Even though this was accomplished to a certain degree, how to identify an old growth forest seems still elusive due to the ecological context of the long-living tree species of the Temperate Forest. Even in old-growth forests, pioneer tree species can coexist with mature shade-tolerant taxa. In the traditional successional models (Donoso 1993), pioneer shade intolerant taxa are supposed to be replaced by shade tolerant taxa in the late stages of succession (in the absence of disturbance). Nevertheless, is not always easy to determine if the structural variability of old stands is related to late successional stages or to other successional pathways because some pioneer species can live up to 500 years (Gutiérrez & Huth 2012). From a wood charcoal perspective, future analysis should evaluate different methodological approaches considering the age composition of the analysed assemblages, which in our case study was not possible due to sampling limitations and the fragmentation of the charcoal material. Maybe the integration with other archaeobotanical lines of evidence could also be evaluated, since, for instance, some wood species produce seed only after 20 years of age (which could be explored from a macro botanical analysis).

Another aspect that needs to be addressed more critically is the concept of native species, commonly used in the ecological and environmental sciences, and frequently mentioned in this dissertation. As a concept, it became more frequent after the 1980´s, when the taxonomic list of the flora of Chile was systematically reviewed and published, and when there was enough information to make the distinction between native, endemic and

introduced species (Kalin-Arroyo, Marticorena & Muñoz 1990, Marticorena & Quezada 1985). Previously, non-introduced plants were commonly denominated natural or autochthonous (in Spanish: *plantas naturales* o *autóctonas*). Apparently, Claudio Gay was one of the first persons to distinguish more systematically the plants according to their status, differentiating the introduced plants since the Spanish conquest (Gay 1845, p.16). Nowadays, there is a consensus, and all plants present in the Chilean territory until the moment of the Spanish arrival are considered native (Silva 2010). This is problematic because, it conditions what is currently understood as the natural distribution of a species, but also masks the anthropic factor that shaped the "native vegetation". While in the North of Chile there is clear evidence of the introduction of trees during pre-Hispanic times (McRostie *et al.* 2017), in Southern Chile the topic has not been addressed. Because of the geographical isolation, islands can provide an initial approach to the transportation and translocation of plants. Preliminarily, the data from Mocha Island shows woody species that are not considered native to the Island appearing in archaeological sites. Maybe once data from different sites is obtained, it will be possible to discuss the link between certain taxa, translocations and settlement or mobility patterns during pre-Hispanic times.

Altogether, the archaeobotanical, ethnohistoric and environmental data shows that the populations from Southern Chile during the Ceramic Period did not inhabit a densely forested landscape, but most likely a landscape that combined open spaces with patches of forest. Previous wood charcoal analysis in Southern Chile have suggested a link between ecotonal spaces and archaeological sites (Solari 2008). The development and maintenance

of ecotonal spaces could have been promoted by the ceramic groups of Southern Chile, especially because these types of spaces can potentially concentrate species with edible and other useful properties.

Going back to the leading question of this dissertation, the wood charcoal record does not show a significant vegetation changes that can be associated with an intensification of agricultural practices and animal management. Overall, all the sites do show changes over time, but they don't represent a drastic vegetal transition from a closed canopy forest to an open land or shrubland. The identified species represent an intermediate stage of forest succession, that combines shade tolerant and shade intolerant species, can be interpreted as of a mosaic landscape that includes open areas, forest patches, and ecotonal spaces (Lara *et al.* 2012).

Finally, for the sites in the continent, the species recognized in the wood charcoal samples contrast strongly with the current landscape. In El Arenal-1, most of the woody taxa surrounding the site today are exotic invading species, and in Cueva de Los Catalanes, the wood charcoal record shows more diversity of taxa than can be recognized around the site today. In the current vegetation distribution of Southern Chile, sclerophyllous species are more and more restricted to northern regions, and lauriphyllous taxa to higher altitude or more isolated zones. Although in modern Southern Chile vegetation is the result of a series of recent historic processes that include economic and political factors with clear ecological consequences, wood charcoal analysis proves to be and adequate approach to provide tangible evidence with a longer chronological perspective about how people in the

past interacted with their landscape, and how human activities have contributed to the distribution of trees and vegetation types.

10.3 Further comments in relation to the wood charcoal analysis in Southern Chile

Although in the recent decades wood charcoal analysis started to be more frequently considered among the archaeobotanical analysis in Chile, some issues need to be addressed and considered for the future development of the discipline.

In the first place, there is a need for experimentation with native taxa from the temperate forest, a situation noted and mentioned more than ten years ago (Solari & Lehnebach 2010). Although in Argentina some studies have addressed through experiments the taphonomy of certain species (Andreoni, Gil & Capparelli 2011, Caruso-Fermé *et al.* 2018, Caruso-Fermé 2013) there is still a lack of experimental programs with different native species and under diverse environmental settings and conditions. Based on the experience of the analysis conducted for this dissertation, it would be interesting to test if hard woods, like the ones from the Myrtaceae family show better preservation in comparison to softer woods (like *Nothofagus*, or *Laurelia/Laureliopsis*) or minor taxa like vines and lianas. Preliminarily, there is a low identification of charcoal from woody climbers and lianas (table 24, appendix A). Unlike other temperate forests, in South America there is a high diversity of woody plants with different habits, like shrubby and sub

shrubby climbers, shrubby and sub shrubby parasites, and sub shrubby epithetic species (Armesto, León & Kalin 1996, Rodriguez *et al.* 2018). One aspect to evaluate in future experimental programs is if woody climbers, because of their anatomical characteristics like big size pores and wide rays (Jiménez-Castillo & Lusk 2013), show more susceptibility to fragmentation and bad preservation. As a precedent, and keeping in mind the ecological differences, lianas have been identified among the wood charcoal assemblages in case studies from Amazonia (Bodin *et al.* 2020).

Although fragmentation was not properly addressed in this study, there is still an ongoing discussion about how different woody taxa react to combustion in terms of fragmentation and how different combustion factors (such as temperature, duration of combustion, environment of combustion) might influence in the final number of charcoal fragments (Allué, Euba & Solé 2009, Théry-Parisot, Chabal & Chrzavzez 2010). In order to contribute to this discussion, it seems pertinent to mention some preliminary observations based on the 2018 analysis of Cueva de Los Catalanes. The consensus indicates that fragmentation of wood charcoal depends on combustion and post-depositional processes, but wood cell structure also influences the final number of charcoal fragments in conditions of mechanical stress (Chrzazvez *et al.* 2014). As a result, fragmentation as well as other processes such as shrinkage vary among species (Smart & Hoffman 1988). Previous studies in South America have suggested that the depositional context might have contributed more to the fragmentation of the assemblage than taxonomic variables (Marconetto 2008), and most of the previous anthracological analysis in south America have adopted the “fragmentation law” proposed by Chabal (1990), which was based on Old

World wood taxa. According to that model, fragmentation of charcoal in archaeological contexts does not relate to a particular woody taxon (each taxon has the same probability to fracture into different fragment sizes), however, when there is not a direct or linear relationship between the number of fragments and their volume or weight, some authors have interpreted that fragmentation was influenced by post depositional processes (Andreoni & Capparelli 2012, Andreoni, Gil & Capparelli 2011). Following Marconetto (2008), in order to evaluate which taxon presented the bigger and the smaller charcoal fragments, a fragmentation rate was calculated dividing the total mass of each taxon (gr), by the total number of fragments (details in figure 2, appendix A). Although only four taxa were used to calculate the fragmentation rate, it was noticed that the values were different according to each taxon. Considering the anatomical features of different taxa, experimental and archaeological approaches indicates that taxa with certain anatomical features (such as large vessels, marked porous areas and long radial file vessels) produces more fragments (Chrzazvez *et al.* 2014), and that prioritizing the analysis of the over 4 mm charcoal fragments can lead to an overrepresentation of the most frequently recovered taxa (Henry et al. 2020). In our preliminary data, Myrtaceae type A and type B were more prone to bigger charcoal fragments in comparison to *Nothofagus* sp. and *Drimys winteri*. In general terms, the Myrtaceae family presents a diffuse-porous wood, with small vessel elements (Rancusi, Nishida & Nishida 1987), and several of their species are considered hard and durable wood (Rodríguez, Matthei & Quezada 1983). The *Nothofagus* genus usually presents radial series of pores (2 to 10), some vessel clusters are commonly registered (Rancusi, Nishida & Nishida

1987), and is considered a wood of medium durability. *Drimys winteri* does not have vessel elements and is consider a soft angiosperm wood (Rodríguez, Matthei & Quezada 1983). The anatomical features of these last two taxa might then increase the probability to produce smaller fragments of charcoal, nevertheless, to establish if the situation responds to post depositional conditions, more samples must be analysed, and adequate data (both archaeobotanical and experimental) should be collected.

From the revision of previous studies (Chapter 6, section 6.3 of this dissertation), there is a strong focus on taxonomical identification, while other topics related to taphonomic features, like firewood procurement (gathering of dead wood versus green ones), or the incidence of post-depositional processes are almost non-existent in Southern Chile.

Strongly related to this lack of a taphonomical approach is the issue of sampling. In general, archaeobotanical flotation samples in Southern Chile are small (usually less than 7 litres of sediment for each ten centimetres of deposit), and sometimes the wood charcoal comes mostly from handpicked samples taken during the excavation (El Arenal-1 is a good example of this). Recent research projects have implemented systematic sampling and flotation, but there is still no standardization, especially in the commercial archaeology sector. Since the analysis from this dissertation included excavation handpicked charcoal and flotation samples, it was possible to contrast the results obtained from both strategies. Firstly, since vitrification produces a hardening of the wood charcoal fragments (more resistance to structural collapse and fragmentation), working only with excavation

samples can lead to an overrepresentation of larger but vitrified fragments (and if the vitrification is severe, identification is difficult). And secondly, the presence of biological indicators of wood decay such as hyphae and xylophage insects were almost exclusively registered in flotation samples. Although it could seem evident, large volume flotation samples are not only important in relation to charred seed recovery, but they are also relevant when analysing wood charcoal since handpicking can lead to wood charcoal assemblages with low taxa richness (Henry *et al.* 2020). Otherwise, it will be difficult to direct the wood charcoal analysis beyond taxa identification. Since some case studies show that water flotation might favoured the recovery and preservation of vitrified fragments (Arranz-Otaegui 2017), future analysis should also evaluate if water flotation might be also a bias in the representation of the wood charcoal assemblages from Southern Chile.

Finally, there is a need of more integrative approaches in archaeobotanical analysis combining different lines of evidence (including macro and micro remains). Topics like seasonality, for instance, could be explored through comprehensive studies that include wood charcoal, seeds, and archaeometric proxies. Another topic rarely studied is the relation between climatic and environmental conditions and the taxa representation in the archaebotanical record. While certain species like the Myrtaceae family produce fruit every year (Smith-Ramírez, Armesto & Figueroa 1998), other species produce seeds and fruits every 2-4 years, or even less regularly being the *Chusquea* genus an extreme example of flowering processes that can take up to 50-70 years (Tagle *et al.* 2013). These ecological aspects, which for some species are related to climatic conditions like dry summers,

should be taken in consideration when interpreting the ubiquity and frequency of charred seeds and interpretation of availability of resources.

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APPENDIX A:

SUPPLEMENTARY INFORMATION FOR CHAPTERS 4 TO 10.

Table 1: Camelidae taxon dates of Southern Chile. Abbreviations: CLC= Cueva de los Catalanes, IM= Mocha Island The calibration was done in OxCal 4.4 using the SHCal20 calibration curve (Hogg *et al.* 2020).

Site and Unit	Lab Code	Date	±	Modelled (CE)		References
				from_95.4	to_95.4	
CLC, U1 (160-170)	AA111538	1527	24	535	635	Campbell *et al.* 2020
CLC, U2 (150-160)	UGAMS 27387	1410	25	601	660	Campbell *et al.* 2020
MI, P25-1	AA108935	1055	25	897	1030	Campbell *et al.* 2020
MI, P29-1	AA108938	821	24	1175	1262	Campbell *et al.* 2020
MI, P25-1	AA108932	758	23	1225	1272	Campbell *et al.* 2020
MI, P12-1	UB29286	753	27	1234	1278	Campbell *et al.* 2020
MI, P5-1	UB26213	751	35	1247	1238	Campbell & Pfeiffer 2017
MI, P23-1	AA108928	740	23	1263	1285	Campbell *et al.* 2020
MI, P12-1	UB29282	744	32	1269	1290	Campbell *et al.* 2020
MI, P29-1	AA108937	654	23	1276	1297	Campbell *et al.* 2020
MI, P5-1	UB24528	668	26	1276	1301	Campbell *et al.* 2020
MI, P25-1	AA108930	687	33	1277	1304	Campbell *et al.* 2020
MI, P22-1	AA108921	709	23	1280	1373	Campbell *et al.* 2020
MI, P5-1	UB24529	683	26	1281	1377	Campbell *et al.* 2020
MI, P31-1	AA108939	706	23	1284	1379	Campbell *et al.* 2020
MI, P25-1	AA108934	703	23	1286	1380	Campbell *et al.* 2020
MI, P23-1	AA108929	700	23	1289	1385	Campbell *et al.* 2020
MI, P5-1	AA108920	611	23	1300	1398	Campbell *et al.* 2020
MI, P5-1	UB26216	605	26	1311	1406	Campbell *et al.* 2020
MI, P22-1	AA108924	572	23	1329	1424	Campbell *et al.* 2020
MI, P22-1	AA108922	453	23	1422	1455	Campbell *et al.* 2020
MI, P25-1	AA108931	428	23	1437	1473	Campbell *et al.* 2020
MI, P23-2	AA108926	400	23	1446	1502	Campbell *et al.* 2020

Figure 1: Taxon dates of Camelids in Southern Chile

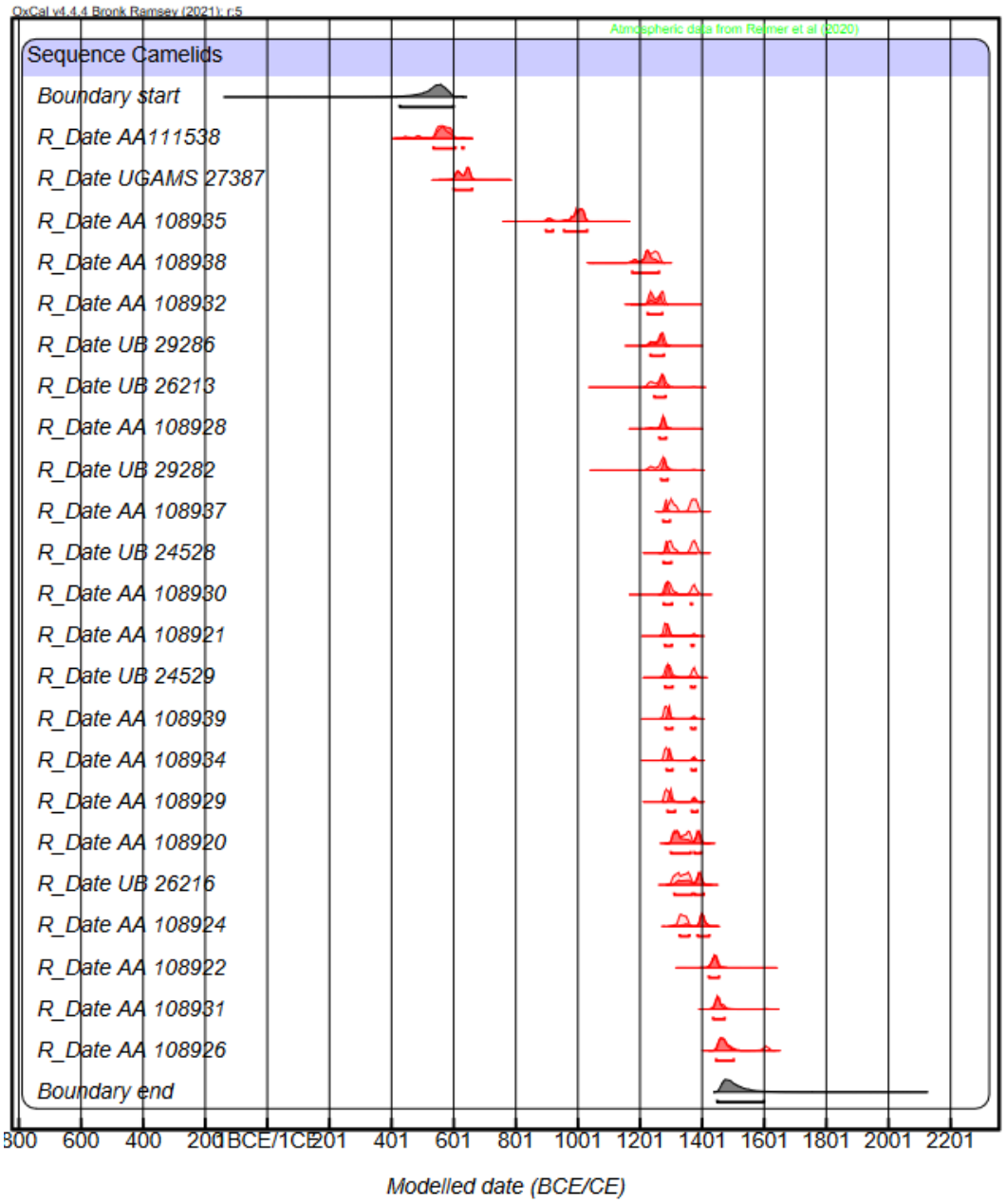


Table 2. Taxonomic list of the modern reference collection of woody taxa from Southern Chile. Most of the specimens were collected by the author, but some come from bigger reference collection of Universidad de Chile (UCH) and Universidad Austral de Chile (UACH). The samples from UCH were given from the xylotec of the Laboratorio de Anatomía de Maderas, Facultad de Ciencias Forestales y de la Conservación de la Naturaleza, under place and date of collection they were listed as X.I.A.M. (the 2013 year stands for year of obtention and not for original year of collection, which is unknown). The samples from UACH were given from the reference collection of the Archaeobotany Laboratory, and for some of these samples there is missing information such as date and place of collection. As reference, most of the samples were collected around the year 1999, and they were identified by Carlos Adolfo Lehnebach (Botanist). The herbarium of these samples used to be in the Science Building (Isla Teja Campus, Valdivia) but it was lost on fire (2007).

Family	**Scientific name**	**N**	**Place and Date of collection**
Araucariaceae	*Araucaria araucana* (Molina) K.Koch	1	Icalma, Feb. 2014
Aextoxicaceae	*Aextoxicon punctatum* Ruiz & Pav.	2	C. Ñielol 2013; Mocha I. 2014
Anacardiaceae	*Lithrea caustica* Hook. & Arn.	1	Tabito, Jan. 2016
	Schinus latifolius (Gillies ex Lindl.) Engl.	1	Tabito, Jan. 2016
	Schinus polygamus (Cav.) Cabrera	1	UACH
Araliaceae	*Raukaua laetevirens* (Gay) Frodin	2	Mocha I. 2015, Pucón 2022
Asteraceae	*AcrisiJone denticulata* (Hook. & Arn.) B. Nord.	1	UACH
	Baccharis linearis (Ruiz & Pav.) Pers.	2	Coñaripe (UACH), La Plata 2019
	Baccharis rhomboidalis J. Remy	1	UACH
	Baccharis sp.	1	La Plata, Jan. 2019
	Chuquiraga oppositifolia D.Don	1	La Plata, Jan. 2019
	Eupatorium salvium Colla	1	UACH
	Leptocarpha rivularis DC	2	Mocha I. 2014
	Proustia sp.	1	La Plata 2019
	Podanthus mitiqui Lindl.	1	UACH
Berberidaceae	*Berberis actinacantha* Mart. ex Schult. & Schult.f.	1	Taltal, Oct. 2015
	Berberis darwinii Hook.	1	Calfuco (UACH)
	Berberis empetrifolia Lam.	1	La Plata Jan. 2019
	Berberis microphylla G.Forst.	1	Pta. Arenas 2014
	Berberis sp.	2	Icalma, Feb. 2014; La Plata, Jan. 2019
Campanulaceae	*Lobelia tupa L.*	1	Mocha I. 2014
Celastraceae	*Maytenus boaria* Molina	1	La Plata, Jan. 2019
Columelliaceae	*Desfontainia fulgens* D. Don	1	Huerquehue 2022

Table 2 (continuation). Reference collection of woody taxa, Southern Chile

Family	Scientific name	N	Place and Date of collection
Cunoniaceae	*Caldcluvia paniculata (*Cav.) D.Don	1	Mocha I., Jan. 2015
	Eucryphia cordifolia Cav.	2	Pto. Montt 2019; X.I.A.M 2013
	Weinmannia trichosperma Cav.	1	Llancahue (UACH)
Cupressaceae	*Austrocedrus chilensis* (D.Don) Pic.Serm. & Bizzarri	1	La Plata, Jan. 2019
	Fitzroya cupressoides (Molina) I.M.Johnst.	1	Pto. Montt, Feb. 2015
	Pilgerodendron uviferum (D. Don) Florin	1	UACH
Eleocarpaceae	*Aristotelia chilensis* (Molina) Stuntz	3	Isla Cautín 2013; Mocha I. 2014
	Crinodendron patagua Molina	2	Valdivia 2022; UACH
Ephedraceae	*Ephedra chilensis* C.Presl	1	Angol, May 2017
	Ephedra sp.	1	Taltal, Oct. 2015
Escalloniaceae	*Escallonia pulverulenta* (Ruiz & Pav.) Pers.	1	UACH
	Escallonia revoluta (Ruiz & Pav.) Pers	1	Tabito, Dec. 2014
	Escallonia rubra (Ruiz & Pav.) Pers.	1	La Plata, Jan. 2019; Caburgua 2022
	Escallonia serrata Sm.	1	UACH
	Escallonia sp.	1	La Plata, Jan. 2019
Ericaceae	*Gaultheria phillyreifolia (*Pers.) Sleumer	1	Loncoche (UACH)
Fabaceae	*Acacia caven* (Molina) Molina	1	Melipilla, May 2019
	Adesmia sp.	1	UACH
	Otholobium glandulosum (L.) J.W. Grimes	1	Angol, May 2017
	Senna stipulacea (Aiton) H.S.Irwin & Barneby	1	Mocha I., Jan. 2014; UACH
	Sophora sp.	1	Lumaco, May 2017
Gesneriaceae	*Mitraria coccinea* Cav.	1	Mocha I., Jan. 2014
Gomortegaceae	*Gomortega keule* (Molina) Baill.	1	UACH
Griseliniaceae	*Griselinia jodinifolia* (Griseb.) Taub.	1	Calfuco (UACH)
Grossulariacea e	*Ribes* sp.	2	Mocha I., Jan. 2015; Huerquehue 2022
Hydrangeaceae	*Hydrangea serratifolia* (Hook. & Arn.) F. Phil	2	Mocha I., Jan. 2015; Huerquehue 2022
Lauraceae	*Cryptocarya alba* (Molina) Looser	1	Antumapu, Oct. 2013
	Persea lingue (Miers ex Bertero) Nees	2	X.I.A.M, Oct. 2013
Loranthaceae	*Notanthera heterophyllus (*Ruiz & Pav.) G.Don	1	Mocha I., Jan. 2014, Pucón 2022
Luzuriagaceae	*Luzuriaga radicans* Ruiz & Pav.	1	Mocha I., Jan. 2014
Malvaceae	*Corynabutilon* sp.	1	UACH

Table 2 (continuation). Reference collection of woody taxa, Southern Chile

Family	Scientific name	N	Place and Date of collection
Monimiaceae	*Laureliopsis philippiana (*Looser) Schodde	1	Huerquehue, Feb. 2014
	Laurelia sempervirens Tul.	2	Mocha I., Jan. 2013, Jan.2014
	Peumus boldus Molina	3	Isla Cautín 2013; Mocha I. 2014
Myrtaceae	*Amomyrtus luma* (Molina) D. Legrand & Kausel	1	Mancera (UACH)
	Amomyrtus meli (Phil.) D. Legrand & Kausel	1	Llancahue, Valdivia (UACH)
	Blepharocalyx cruckshanksii (Hook. & Arn.) Nied.	2	Mocha I. 2015; Lanalhue Lake 2014
	*Luma apiculata (*DC.) Burret	3	C. Ñielol 2013; Antumapu 2013; Mocha I. 2014
	Myrceugenia planipes (Hook. & Arn.) O. Berg	1	Mocha I., Jan. 2015; UACH
	Myrceugenia exsucca (DC.) O. Berg	1	UACH
	Tepualia stipularis (Hook. & Arn.) Griseb.	2	Mocha I., Jan. 2014; Lanalhue Lake 2014
	Ugni sp.	2	Caburgua 2022; UACH
Nothofagaceae	*Nothofagus alpina* (Poepp. & Endl.) Oerst.	1	X.I.A.M, Oct. 2013; UACH
	Nothofagus antarctica (G. Forst.) Oerst.	1	UACH
	Nothofagus dombeyi (Mirb.) Oerst.	1	Temuco, Sep. 2013
	Nothofagus nitida (Phil.) Krasser	1	UACH
	Nothofagus obliqua (Mirb.) Oerst.	1	Temuco, Sep. 2013
Onagraceae	*Fuchsia magellanica* Lam.	1	Mocha I., Jan. 2014
Poaceae	*Chusquea* sp.	1	Coñaripe 2016, Huerquehue 2022
Podocarpaceae	*Podocarpus saligna* D. Don	1	X.I.A.M, Oct. 2013
	Podocarpus nubigenus Lindl.	1	Pto. Montt, Mar. 2019
	Prumnopitys andina (Poepp. ex Endl.) de Laub.	1	UACH
	Saxegothaea conspicua Lindl.	1	Los Pellines (UACH), Huerquehue 2022
Polygonaceae	*Muehlenbeckia hastulata* (Sm.) I.M. Johnst	2	Mocha I., Jan. 2014; Tabito, Dec. 2014
Proteaceae	*Embothrium coccineum* J.R. Forst. & G. Forst.	1	Valdivia 2022
	Gevuina avellana Molina	2	Temuco, Sep. 2013
	Lomatia dentata (Ruiz & Pav.) R. Br	1	C. Ñielol, Sep. 2013
	Lomatia ferruginea (Cav.) R. Br	1	Pto. Montt Mar. 2019
	Lomatia hirsuta (Lam.) Diels	1	Angol, May 2017
Quillajaceae	*Quillaja saponaria* Molina	1	Antumapu, Oct. 2013

Table 2 (continuation). Reference collection of woody taxa, Southern Chile

Family	Scientific name	N	Place and Date of collection
Rhamnaceae	*Discaria* sp.	1	UACH
	Rhammus diffusus Clos	1	Llancahue, Valdivia 1999
	Trevoa quinquenervia Gillies & Hook.	1	UACH
Rosaceae	*Kageneckia oblonga* Ruiz & Pav.	1	San Ramón, Aug. 2019
	Tetraglochin alatum (Gillies ex Hook. & Arn.) Kuntze	1	La Plata 2019
Salicaceae	*Azara integrifolia* Ruiz & Pav	1	Coñaripe, 1999
	Azara lanceolata Hook.f.	1	Mocha I., Jan. 2015
	Salix sp.	2	Cautin 2013, Pucon 2022
Santalaceae	*Myoschilos oblongum* Ruiz & Pav.	1	Petrohue (UACH)
Scrophulariaceae	*Buddleja globosa* Hope	1	Mocha I., Jan. 2014
Solanaceae	*Cestrum parqui* (Lam.) L'Hér	2	Angol, May 2015; UACH
	Fabiana imbricata Ruiz & Pav.	1	UACH
	Latua pubiflora (Griseb.) Baill.	1	UACH
	Vestia foetida Hoffmanns.	1	Mocha I., Jan. 2014
Thymelaeaceae	*Ovidia andina* (Poepp. & Endl.) Meisn.	1	UACH
	Ovidia pillo-pillo (Gay) Meisn.	1	UACH
Verbenaceae	*Rhaphithamnus spinosus* (Juss.) Moldenke	3	Mocha I. 2013, 2014; Puerto Montt 2019
Vitaceae	*Cissus striata* Ruiz & Pav.	2	Temuco, Sep. 2013; Mocha I., Jan. 2014
Winteraceae	*Drimys winteri* J.R. Forst. & G. Forst	3	Temuco, Sep. 2013; Mocha I., Jan. 2014, Huerquehue 2022

Table 3: Mocha Island, archaeobotanical data from charred seeds (X) and micro remains analysis (0), references: Roa *et al*. 2021, Godoy-Aguirre 2018.

HERBACEOUS TAXA		ARCHAEOLOGICAL SITE						
Family	**Identified taxa**	**P29-1**	**P31-1**	**P5-1**	**P12-1**	**P25-1**	**P23-2**	**P22-1**
Aizoaceae	*Tetragonia tetragonioides*					X		
Amaranthaceae	cf. *Atriplex* sp.			X				
	Chenopodium album					X	X	X
	Chenopodium ambrosioides					X	X	X
	Chenopodium quinoa	X	X	X	X	X	X	X
	Chenopodium sp.	X	X	X	X	X	X	X
Asteraceae	Asteraceae		X	X			X	
	Cirsium sp.							X
	Madia sativa		X	X	X			
	cf. *Madia sativa*		0					
	Madia spp.							X
Brassicaceae	Brassicaceae			X		X	X	X
Caryophyllaceae	cf. Caryophyllaceae			X				
	Silene gallica				X			X
	Stellaria media						X	X
Cyperaceae	Cyperaceae	X	X	X 0	X	X	X	X
	cf. *Schoenoplectus* sp.		X					
	Cyperus sp.	X	X	X				
	cf. *Eleocharis* sp.			X				
	Schoenoplectus californicus		X	X	X	X		X
	Schoenoplectus cf. *americanus*	X						
Euphorbiaceae	Euphorbiaceae						X	
	cf. *Dysopsis glechomoides*			X				
Fabaceae	Fabaceae	X	X	X		X	X	X
	cf. Fabaceae			X	X	X	X	X
	Phaseolus vulgaris	X					X	
	cf. *Phaseolus vulgaris*		0					
	Phaseolus sp.			X				
	cf. *Phaseolus* sp.			X			X	
Gunneraceae	cf. *Gunnera tinctoria*		0	0			X	
Juncaceae	Juncaceae					X		X
Lamiaceae	*Salvia officinalis*					X		
Malvaceae	Malvaceae						X	
Papaveraceae	Papaveraceae							X
Poaceae	Poaceae	X		X	X	X	X	X
	Bromus spp.	X	X	X		X	X	X
	Eragrostis sp.					X		
	Zea mays	X	X	X 0	X	X	X	X
	cf. *Zea mays*	X	X0	X	X	X		X
Plantaginaceae	*Plantago* spp.			X	X			
Polygonaceae	Polygonaceae	X		X	X	X		
Rosaceae	Rosaceae	X		X	X	X		X
	Fragaria chiloensis	X	X	X		X	X	
	Rubus cf. *geoides*	X	X	X	X	X	X	X
Rubiaceae	Rubiaceae	X		X		X	X	X
Solanaceae	*Datura* sp.					X		
	cf. *Solanaceae*			X				

Table 3 (continuation): Mocha Island, archaeobotanical data from charred seeds (X) and micro remains analysis (0), references: Roa *et al*. 2021, Godoy-Aguirre 2018.

WOODY TAXA		ARCHAEOLOGICAL SITE						
Family	**Identified taxa**	**P29-1**	**P31-1**	**P5-1**	**P12-1**	**P25-1**	**P23-2**	**P22-1**
Anacardiaceae	cf. Anacardiaceae			X				
Alstroemeriaceae	*Luzuriaga radicans*	X						
Cactaceae	Cactaceae						X	
	cf. Cactaceae			X				
Coriariaceae	*Coriaria ruscifolia*				X	X		
Elaeocarpaceae	*Aristotelia chilensis*	X	X	X	X	X	X	X
	cf. *Aristotelia chilensis*			0				
Gesneriaceae	cf. *Mitraria coccinea*			X				
Lauraceae	*Cryptocarya alba*		X					
	cf. *Cryptocarya alba*			X				
Monimiaceae	*Peumus boldus*			X			X	
Myrtaceae	*Luma apiculata*			X				
	cf. *Luma apiculata*			0				
	Ugni spp.	X	X				X	
	cf. *Ugni* spp.			X				
Onagraceae	cf. *Fuchsia magellanica*			0				
Philesiaceae	*Lapageria rosea*		X					
Poaceae	cf. *Chusquea* sp.	0						
Polygonaceae	*Muehlenbeckia hastulata*		X					
Proteaceae	*Gevuina avellana*	X	X					
Vitaceae	*Cissus striata*		X					
Winteraceae	*Drimys winteri*		X					X
	cf. *Drimys winteri*			X				

Table 4: Woody taxa present in Mocha Island according to Reiche (1903) and Kunkel (1968). R= Reiche, K= Kunkel, P= present, A= absent, in blank= not mentioned. Habitus or life form: T=tree, CS= climbing shrub, ST=small tree, SS= subshrub, PS= parasite shrub, CSS= climbing subshrub.

Family	Species	Habitus	R	K
Aextoxicaceae	*Aextoxicon punctatum* Ruiz & Pav	T	P	P
Apocynaceae	*Elytropus chilensis* (A. DC.) Müll. Arg	CS	P	P
Araliaceae	*Raukaua laetevirens* (Gay) Frodin	ST or S	P	P
	Raukaua valdiviensis (Gay) Frodin	CS	P	P
Asteraceae	*Baccharis racemose* (Ruiz & Pav.) DC	S	P	P
	Leptocarpha rivularis DC	S	P	P
	Dasyphyllum diacanthoides (Less.) Cabrera	T	P	P
Calceolariaceae	*Calceolaria integrifolia* L.	S or SS	P	
Cunoniaceae	*Eucryphia cordifolia* Cav	T	P	P
	Caldcluvia paniculata (Cav.) D. Don	T	P	P
Elaeocarpaceae	*Aristotelia chilensis* (Molina) Stuntz	T	P	P
Escalloniaceae	*Escallonia rubra* (Ruiz & Pav.) Pers. var. rubra	S	P	P
	Escallonia rubra (Ruiz & Pav.) Pers. var. *macrantha* (Hook. & Arn.) Reiche	S	P	
Fabaceae	*Acacia caven* (Molina) Molina	T	P	P
	Senna stipulacea (Aiton) H.S. Irwin & Barneby var. *stipulacea*	S	P	P
Gesneriaceae	*Mitraria coccinea* Cav	CS	P	P
Griseliniaceae	*Griselinia scandens* (Ruiz & Pav.) Taub	S		P
Grossulariaceae	*Ribes punctatum* Ruiz & Pav.	S	P	
	Ribes valdivianum Phil.	S		P
Hydrangeaceae	*Hydrangea serratifolia* (Hook. & Arn.) F. Phil.	CS	P	P
Lamiaceae	*Teucrium bicolor* Sm	S	P	P
	Gardoquia multiflora Ruiz & Pav	S	P	
Lauraceae	*Persea lingue* (Ruiz & Pav.) Nees	T	P	P
Loranthaceae	*Notanthera heterophylla* (Ruiz & Pav.) G. Don	PS	P	P
Luzuriagaceae	*Luzuriaga polyphylla* (Hook.) J.F. Macbr	CSS		P
	Luzuriaga radicans Ruiz & Pav.	CS	P	P
Monimiaceae	*Laurelia sempervirens* (Ruiz & Pav.)	T	P	P
	Peumus boldus Molina	T	P	P
Myrtaceae	*Ugni molinae* Turcz.	S	P	
	Ugni candollei (Barnéoud) O. Berg	S		P
	Amomyrtus luma (Molina) D. Legrand & Kausel	T	P	P
	Blepharocalyx cruckshanksii (Hook. & Arn.) Nied.	T	P	P
	Myrceugenia planipes (Hook. & Arn.) O. Berg	T	P	P
	Myrceugenia exsucca (DC.) O. Berg	T		P
	Luma apiculata (DC.) Burret	T	P	P
Onagraceae	*Fuchsia magellanica* Lam.	S	P	P
Philesiaceae	*Lapageria rosea* Ruiz & Pav	CS	A	P
Phytolaccaceae	*Ercilla spicata* (Bertero) Moq	CS	P	
Polygonaceae	*Muehlenbeckia hastulata* (Sm.) I.M. Johnst. var. *fascicularis* (Meisn.) Brandbyge	S	P	P
Proteaceae	*Gevuina avellana* Molina	T	P	P
Rhamnaceae	*Rhamnus diffusus* Clos	S	P	P
Rosaceae	*Margyricarpus digynus* (Bitter) Skottsb.	SS	P	
Salicaceae	*Azara lanceolata* Hook.f.	S or ST	P	P
	Salix humboldtiana Willd.	T		P
Scrophulariaceae	*Buddleja globosa* Hope	S	P	P
Solanaceae	*Cestrum parqui* L'Hér.	S	P	P
	Vestia foetida Hoffmanns.	S	P	P
Thymelaeaceae	*Ovidia pillo-pillo* (Gay) Meisn	S	P	P
Urticaceae	*Pilea elegans* Gay	SS	P	P
Verbenaceae	*Rhaphithamnus spinosus* (Juss.) Moldenke	S	P	P
Vitaceae	*Cissus striata* Ruiz & Pav	CS	P	P
Winteraceae	*Drimys winteri* J.R. Forst. & G. Forst. var. *winteri*	T	P	P

Table 4 (continuation): Woody and other relevant taxa absent in Mocha Island according to Reiche (1903) and Kunkel (1958). R= Reiche, K= Kunkel, P= present, A= absent, in blank= not mentioned. Habitus or life form: T=tree, CS= climbing shrub, ST=small tree, SS= subshrub, PS= parasite shrub, PSS= parasite subshrub, CSS= climbing subshrub, HP= herbaceous perennial,

Family	Species	Habitus	R	K
Asteraceae	*Mutisia* sp.	S, CS or CSS	A	A
	Senecio sp.	S or SS	A	
Berberidaceae	*Berberis* sp.	S or ST	A	A
Bromeliaceae	*Greigia sphacelata* (Ruiz & Pav.) Regel	HP		P
	Fascicularia bicolor (Ruiz & Pav.) Mez subsp. bicolor	HP epiphytic or terrestrial	P	P
Calceolariaceae	*Jovellana punctata* Ruiz & Pav	S	A	
Campanulaceae	*Lobelia tupa* L.	HP	P	P
Cunoniaceae	*Weinmannia trichosperma* Cav.	T	A	
Fabaceae	*Sophora macrocarpa* Sm.	S or ST	A	
	Sophora cassioides (Phil.) Sparre	T	A	
Gesneriaceae	*Sarmienta scandens* (J.D. Brandis ex Molina) Pers.	Epiphytic SS	A	
Griseliniaceae	*Griselinia ruscifolia* (Clos) Ball	S	A	
Lardizabalaceae	*Boquila trifoliolata* (DC.) Decne.	CS	A	
	Lardizabala	CS		A
Lauraceae	*Cryptocarya*	T		A
Misodendraceae	*Misodendrum* sp.	PSS	A	
Nothofagaceae	*Nothofagus obliqua* (Mirb.) Oerst.	T	A	A
	Nothofagus dombeyi (Mirb.) Oerst.	T	A	A
	Nothofagus alpina (Poepp. & Endl.) Oerst	T	A	A
Podocarpaceae	*Podocarpus saligna* D. Don	T	A	A
Poaceae	*Bromus catharticus* Vahl var. elatus (E. Desv.) Planchuelo	HP annual or biennial		P
	Bromus lithobius Trin.	HP	P	P
	Bromus uniloides	HP annual or biennial	P	P
	Chusquea valdiviensis E. Desv	HP	P	
	Chusquea quila Kunth	HP		P
Proteaceae	*Embothrium coccineum* J.R. Forst. & G. Forst	T	A	A
	Lomatia	T or S		A
Rhamnaceae	*Colletia* sp.	S	A	
	Discaria sp.	S or ST	A	
Rosaceae	*Fragaria chiloensis* (L.) Mill	HP	P	P

Table 5: Details of the ^{14}C dates for the P5-1 site. The calibration was done in OxCal 4.4 using the SHCal20 calibration curve.

Taxa	TP Unit	Depth (cm)	Lab Code	Date	±	Modelled (BCE/CE)		Reference
						from_95.4	to_95.4	
Pudu puda	05.01.01	90-100	AA 108919	3651	29	-2135	-1933	Campbell & Pfeiffer 2017
Pudu puda	05.01.01	80-85	UB 26212	3566	32	-2022	-1774	Campbell & Pfeiffer 2017
Charcoal	-	100-110	Beta 73675	1210	110	854	1019	Campbell & Pfeiffer 2017
Fuchsia magellanica	05.02.03	105-110	OXA-44144	1136	17	887	988	This thesis
Homo sapiens	-	Superfitial	OxA 34844	1022	30	980	1147	Campbell & Pfeiffer 2017
Homo sapiens	-	-	AA 110795	1021	27	986	1124	Campbell et al. 2020
Zea mays	06.01.01	90-95	UB 24526	992	30	993	1155	Campbell & Pfeiffer 2017
Chenopodium quinoa	06.01.01	35-40	UB 24523	816	27	1176	1274	Campbell & Pfeiffer 2017
Zea mays	06.01.01	70-75	UB 24525	796	25	1218	1275	Campbell & Pfeiffer 2017
Camelidae	06.01.01	35-40	UB 26213	751	35	1221	1297	Campbell & Pfeiffer 2017
Charcoal	-	50-60	Beta 73674	740	100	1127	1405	Campbell & Pfeiffer 2017
Chenopodium quinoa	06.01.01	55-60	UB 24524	718	22	1266	1376	Campbell & Pfeiffer 2017
Fuchsia magellanica	05.02.03	65-70	OXA-44145	706	17	1272	1300	This thesis
Camelidae	05.01.01	20-25	UB 24529	683	26	1275	1389	Campbell & Pfeiffer 2017
Camelidae	05.02.01	30-35	UB 24528	668	26	1279	1390	Campbell & Pfeiffer 2017
Fuchsia magellanica	05.02.03	40-45	OXA-44146	666	17	1282	1389	This thesis
Zea mays	05.02.03	65-70	UB 26215	635	25	1290	1397	Campbell & Pfeiffer 2017
Camelidae	05.02.03	60-65	AA 108920	611	23	1301	1400	Campbell & Pfeiffer 2017
Camelidae	05.02.03	85-90	UB 26216	605	26	1301	1403	Campbell & Pfeiffer 2017
Zea mays	05.02.03	40-45	UB 26214	552	26	1391	1429	Campbell & Pfeiffer 2017
Homo sapiens	-	-	AA 109585	506	25	1401	1441	Campbell & Pfeiffer 2017

Table 6: Wood charcoal fragments with taphonomy markers from TP 05.02.03. V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse, XI: xylophage insect.

Wood charcoal taxa or category	V	V+C	V+H	V+C+H	V+C+I	V+I	C	C+H	C+XI	H	H+SC	XI	I	SC
Myrtaceae	80		2				1	1		2			1	
Laurelia/Laureliopsis	18									1		1		
Fuchsia magellanica	2	2					2	1	1			1		
Cunoniaceae	8	1												
Aextoxicon punctatum	4	1								1				
Peumus boldus	4	1					1							
Schinus sp.	3						1			1				
Aristotelia chilensis	2			1										
Asteraceae		1					1							
Rosaceae	2													
Cryptocarya alba										1				
Buddleja sp.	1													
Maytenus sp.	1													
Ribes sp.													1	
Lauraceae	1													
non-identifiable	85	21	3	2	1	2	8	3		5	1	1	7	7
Unknown	29	3	1				5	1		3			1	
Total	240	30	6	3	1	2	19	6	1	14	1	3	10	7

Table 7. Wood charcoal results from TP 06.01.01 (% = percentage among identified fragments, U= ubiquity). Some of the taxa were updated from original ones mentioned in Delgado (2017), following the Chilean vascular flora catalogue from Rodríguez *et. al* (2018). Other taxa names were modified to homologue the ones used in this dissertation.

Class	**Family**	**Genus/species**	**N**	**%**	**U**
Magnoliopsida (Dicots)	Aextoxicaceae	*Aextoxicon punctatum*	58	8.7	61.9
	Anacardiaceae		1	0.1	4.8
	Araliaceae	*Raukaua* sp.	3	0.4	4.3
	Asteraceae		1	0.1	4.8
	Celastraceae	*Maytenus* sp.	5	0.7	19.0
	Cunoniaceae		47	7.1	61.9
	Elaeocarpaceae		1	0.1	4.8
	Ericaceae		3	0.4	9.5
	Escallonia	*Escallonia* sp.	35	5.3	61.9
	Grossulariaceae	*Ribes* sp.	7	1.1	23.8
	Lauraceae		21	3.2	42.9
		Persea lingue	21	3.2	33.3
	Monimiaceae	*Laurelia/Laureliopsis*	41	6.2	66.17
		Peumus boldus	70	10.6	85.7
	Myrtaceae	Type A	180	27.1	76.2
	Nothofagaceae	*Nothofagus* sp.	3	0.4	9.5
	Onagraceae	*Fuchsia magellanica*	99	14.9	66.7
	Polygonaceae		1	0.1	4.8
	Proteaceae		2	0.3	9.5
	Rosaceae		3	0.4	14.2
	Salicaceae	*Azara* sp.	9	1.4	9.5
	Scrophulariaceae	*Buddleja* sp.	44	6.6	38.1
	Verbenaceae		8	1.2	23.8
	Vitaceae	cf. *Cissus striata*	2	0.3	9.5
Total			665	100	-

Table 8: Wood charcoal fragments with taphonomy markers from TP 06.01.01. H: hyphae, C: radial cracks, V: vitrification, XI: xylophage insect. Reference: Delgado 2017.

Wood charcoal taxa or category	**H**	**XI**	**H + XI**	**H+C**	**C**	**V**
Fuchsia magellanica	10	1		1	19	
Myrtaceae	23	1				
Cunoniaceae	9					
Aextoxicon punctatum	8					
Peumus boldus	7				1	
Lauraceae	2				4	
Escallonia sp.	5					
Laurelia/Laureliopsis	4				1	
Buddleja sp.	3				1	
Rosaceae					2	
Verbenaceae	2					
Persea lingue	1					
Ericaceae	1					
Non-identifiable	19	2	1	1	17	2
Unknown	8			2		
Total	102	4	1	4	45	2

Table 9: Details of the ^{14}C dates for the P29-1 site. The calibration was done in OxCal 4.4 using the SHCal20 calibration curve.

Taxa	TP Unit	Depth (cm)	Lab Code	Date	±	Modelled (CE)		Reference
						from_95.4	to_95.4	
Drimys winteri	29.01.02	110-120	OXA-44147	1083	17	991	1026	This thesis
Charcoal	29.01.02	110-120	AA 89420	1105	36	905	1038	Campbell & Pfeiffer 2017
Charcoal	29.01.02	90-100	AA 89419	964	36	1029	1207	Campbell & Pfeiffer 2017
Fuchsia magellanica	29.01.02	70-80	OXA 44148	971	17	1035	1160	This thesis
Charcoal	29.01.02	30-40	AA 89416	895	38	1049	1274	Campbell & Pfeiffer 2017
Charcoal	29.01.02	50-60	AA 89417	825	36	1186	1289	Campbell & Pfeiffer 2017
Camelidae	29.01.02	70-80	AA 108938	821	24	1220	1280	Campbell & Pfeiffer 2017
Charcoal	29.01.02	70-80	AA 89418	759	38	1225	1383	Campbell & Pfeiffer 2017
Camelidae	29.01.02	20-30	AA 108937	654	23	1298	1397	Campbell & Pfeiffer 2017
Fuchsia magellanica	29.01.02	35-40	OXA 44149	645	17	1309	1400	This thesis

Table 10: Wood charcoal fragments with taphonomy markers from TP 29.01.02. V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse, XI: xylophage insect.

Wood charcoal taxa or category	**V**	**V+C**	**V+H**	**V+C+H**	**V+I**	**V+XI**	**V+SC**	**C**	**C+H**	**H**	**H+SC**	**H +XI**	**H+SC+XI**	**XI**	**I**	**XI+ I**	**SC**
Myrtaceae	110					1		1		13		1	1	10	3		
Fuchsia magellanica	3	6						6							1		1
Ericaceae	3							1						1			
Asteraceae	2							2									
Ribes sp.								2		1							
Cunoniaceae	1													1			
Nothofagus sp.		1								1							
Peumus boldus	1	1															
Myrtaceae B										1							
Monocot	1																
Unknown *B*		2						3		1							
Unkown	11	2						1						1	1	1	
Non-identifiable	138	24	1	3	9	1	1	6	1	4	1			4	20		10
Total	270	36	1	3	9	2	1	22	1	21	1	1	1	17	25	1	11

Table 11. Wood charcoal results from TP 31.02.01 (% = percentage among identified fragments, U= ubiquity). Some of the taxa were updated from original ones mentioned in Delgado (2017), following the Chilean vascular flora catalogue from Rodríguez *et. al* (2018). Other taxa names were modified to homologue the ones used in this dissertation.

Class	Family	Genus/species	N	%	U
Pinopsida			1	0.1	6.2
Magnoliopsida (Dicots)	Aextoxicaceae	*Aextoxicon punctatum*	53	8.5	62.5
	Anacardiaceae		3	0.5	18.7
	Araliaceae	*Raukaua* sp.	3	0.5	12.5
	Asteraceae		5	0.8	31.2
	Celastraceae	*Maytenus* sp.	6	0.9	25
	Cunoniaceae		78	12.6	93.7
	Elaeocarpaceae		7	1.1	31.2
	Ericaceae		1	0.1	6.2
	Escallonia	*Escallonia* sp.	39	6.3	93.7
	Fabaceae		1	0.1	6.2
	Grossulariaceae	*Ribes* sp.	10	1.6	37.5
	Lauraceae		6	0.9	31.2
	Monimiaceae	*Laurelia/Laureliopsis*	24	3.9	56.2
		Peumus boldus	39	6.3	62.5
	Myrtaceae	Type A	225	36.3	100
	Onagraceae	*Fuchsia magellanica*	89	14.3	87.5
	Polygonaceae		2	0.3	12.5
	Proteaceae		3	0.5	18.7
	Rosaceae		2	0.3	12.5
	Scrophulariaceae	*Buddleja* sp.	18	2.9	56.2
	Verbenaceae		2	0.3	12.5
	Vitaceae	cf. *Cissus striata*	2	0.3	12.5
	Winteraceae	*Drimys winteri*	1	0.1	6.2
Total			663	100	-

Table 12: Details of the ^{14}C dates for the P31-1 site, Laguna Huairavos and Mound. The calibration was done in OxCal 4.4 using the SHCal20 calibration curve.

Taxa	Site or Unit	Depth (cm)	Lab Code	Date	±	Modelled (CE)		Reference
						from_95.4	to_95.4	
Charcoal	L. Huairavos		Beta 62523	1760	80	127	524	LeQuesne *et al.* 1999
Charcoal	Mound Profile	475-485	AA 89415	1096	37	892	1045	Campbell & Pfeiffer 2017
Charcoal	P31-1		Gd 6428	840	70	1046	1272	Quiroz & Sánchez 1997
Charcoal	31.02.01	90-100	AA 89424	826	27	1219	1281	Campbell & Pfeiffer 2017
Charcoal	P31-1		Gd 5902	710	50	1263	1365	Quiroz & Sánchez 1997
Charcoal	P31-1		Beta 95086	700	50	1285	1377	Campbell & Pfeiffer 2017
Camelidae	31.02.01	60-70	AA 108939	706	23	1294	1391	Campbell & Pfeiffer 2017
Charcoal	P31-1		Gd 6431	640	90	1318	1416	Quiroz & Sánchez 1997
Charcoal	P31-1		Gd 5901	560	40	1332	1434	Quiroz & Sánchez 1997
Charcoal	P31-1		Gd 7144	530	60	1396	1440	Quiroz & Sánchez 1997
Charcoal	P31-1		Gd 6429	530	80	1406	1446	Quiroz & Sánchez 1997
Charcoal	31.02.01	50-60	AA 89422	510	37	1415	1452	Campbell & Pfeiffer 2017
Charcoal	P31-1		Beta 95085	510	60	1420	1461	Campbell & Pfeiffer 2017
Charcoal	P31-1		Gd 7174	500	40	1429	1479	Quiroz & Sánchez 1997
Charcoal	P31-1		Beta 57811	500	50	1436	1502	Quiroz & Sánchez 1997
Charcoal	P31-1		Gd 7152	450	50	1446	1612	Quiroz & Sánchez 1997
Charcoal	31.02.01	30-40	AA 89 421	408	37	1469	1625	Campbell & Pfeiffer 2017
Charcoal	31.02.01	75-80	AA 89423	334	34	1509	1663	Campbell & Pfeiffer 2017

Table 13. Native wood taxa identified around Cueva de los Catalanes, based on field visits between 2015-2016. Habitus or life form: T=tree, CS= climbing shrub, ST=small tree, and CSS= climbing subshrub.

Family	Species	Habitus
Aextoxicaceae	*Aextoxicon punctatum* Ruiz & Pav	T
Anacardiaceae	*Lithrea caustica* Hook. & Arn.	T
Cardiopteridaceae	Citronella mucronata (Ruiz & Pav.) D.Don	T
Elaeocarpaceae	*Aristotelia chilensis* (Molina) Stuntz	T
Lardizabalaceae	*Lardizabala biternata Ruiz & Pav*	CS
Lauraceae	*Cryptocarya alba* (Molina) Looser	T
Luzuriagaceae	*Luzuriaga radicans* Ruiz & Pav	CSS
Monimiaceae	*Peumus boldus* Molina	T
Myrtaceae	*Luma apiculata* (DC.) Burret	T
Poaceae	*Chusquea culeou* É.Desv.	
Polygonaceae	*Muehlenbeckia hastulata* (Sm.) I.M. Johnst. var. *fascicularis* (Meisn.) Brandbyge	S
Proteaceae	*Lomatia dentata* R.Br.	T
	Lomatia hirsuta (Lam.) Diels	T
Rhamnaceae	*Colletia hystrix* Clos	S
Salicaceae	*Azara* sp.	S or ST
Philesiaceae	*Lapageria rosea* Ruiz & Pav	CS
Vitaceae	*Cissus striata* Ruiz & Pav	CS

Table 14. Details of the ^{14}C dates for the Cueva de los Catalanes site. The calibration was done in OxCal 4.4 using the SHCal20 calibration curve. *Dates from the same sample of *Triticum* sp. grain, calibration made using "R_combine" feature.

Taxa	Unit and Layer	Depth (cm)	Lab Code	Date	±	Modelled (CE)		Reference
						from_95.4	to_95.4	
Canis sp.	U1, L10	180-190	AA111539	1547	24	526	627	Campbell *et al.* 2020
Camelidae	U1, L9	150-160	AA111538	1527	24	552	637	Campbell *et al.* 2020
Myrtaceae B	U1, L10	190-200	OxA-44205	1482	20	595	650	This thesis
Camelidae	U2, L8.3	160-170	UGAMS 27387	1410	25	640	681	Campbell *et al.* 2018
Cryptocarya alba	U2, L8.3	130-140	OxA-44260	1354	16	664	771	This thesis
Drimys winteri	U1, L5	140-150	OxA-44129	1315	32	679	835	This thesis
Phaseolus vulgaris	U2, L8.3	130-140	UGAMS 27386	1300	25	698	880	Campbell *et al*. 2018
Cryptocarya alba	U2, L8.2	120-130	OxA-44261	1143	16	894	994	This thesis
Drimys winteri	U2, L10	170-180	OxA-44258	1012	18	1021	1130	This thesis
Homo sapiens	U2, L8.2	130-140	AA110999	972	23	1040	1153	Campbell *et al.* 2020
Drimys winteri	U2, L8.3	160-170	OxA-44259	967	16	1057	1180	This thesis
Cryptocarya alba	U1, L5	90-100	OxA-44207	919	18	1155	1215	This thesis
Zea mays	U1, L5	90-100	UGAMS 27385	660	20	1296	1392	Campbell *et al.* 2018
Drimys winteri	U2, L7	90-100	OxA-44262	644	16	1320	1401	This thesis
Cryptocarya alba	U1, L5	130-140	OxA-44206	605	18	1333	1422	This thesis
Triticum sp.*	U1, L4	40-50	OxA-44256*	434	16	1453	1497	This thesis
Triticum sp.*	U1, L4	40-50	OxA-44257*	417	17	1453	1497	This thesis
Triticum sp.	U1, L4	50-60	OxA-44255	405	15	1459	1621	This thesis
Triticum sp.	U1, L4	60-70	OxA-44208	343	20	1506	1647	This thesis
Pudu puda	U2, L5	60-70	AA111537	242	37	1632	1804	Campbell *et al.* 2020
Homo sapiens	U2, L5	60-70	AA111000	178	23	1670	1883	Campbell *et al*. 2020
Cryptocarya alba	U2, L4	20-30	OxA-44263	135	18	1692	1926	This thesis

Table 15. Cueva de Los Catalanes, details of sample's weight according to excavation unit and provenience (excavation or flotation).

U1			U2		
Layer/ Depth cm	**Flot.**	**Exc.**	**Layer/ Depth cm**	**Flot.**	**Exc.**
L1 0-10	0.06		L 4 20-30		5.36
L2 10-20	0.08		L4 30-40		3.32
L3 20-30	0.27		L4 40-50		0.33
L3 30-40	0.29		L5 50-60		1.52
L4 40-50	0.93		L5 60-70		7.07
L4 50-60	0.54	0.33	L5 70-80		1.2
L4 60-70	0.46		L6 80-90		0.87
L5 70-80	1.78		L6/L7 80-90	1.91	9.47
L5 80-90	7.64	2.68	L7 80-90		5.31
L5 90-100	6.03		L7 90-100		9.74
L5 100-110	1.81	0.42	L8.1 100-110	0.09	3.95
L5 110-120	2.97	1.85	L8.1 120-130	2.86	
L5 120-130	1.35		L8.2 110-120		3.12
L5 130-140	3.25	0.54	L8.2 120-130		20.85
L5/9.1 140-150	0.73		L8.3 120-130		12.05
L 9.1 150-160	0.44		L8.3 130-140	2.88	17.16
L10 160-170	1.97		L8.3 140-150		13.72
L10 170-180	1.02		L8.3 150-160		20.94
L10 180-190	0.35		L8.3 160-170		2.04
L10 190-200	0.31		L10 170-180		0.84
Total	32.28	5.82	Total	7.74	138.86

Table 16. Wood charcoal fragments with taphonomy markers from U1, Cueva de los Catalanes. V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse.

Taxa	V	SC	H	V+C	C	I	V+H	V+C+H	C+H	H+I	H+SC	V+I	V+C+SC	V+SC	SC+I
Myrtaceae A	11	4	4				1		1		1				
Nothofagus sp.	8	1	6												
Cryptocarya alba	7			1				2	1						
Schinus sp.	7		3				1								
Drimis winteri	1	1	2		3	1				2					
Persea lingue	3		1	1	1				1						
Myrtaceae B			2	2			1		1						
Peumus boldus	2		1	2											1
Lithrea caustica	1	2	1				1								
Fabaceae	1		1			1									
Quillaja Saponaria			3		1										
Maytenus sp.	3														
Aristotelia chilensis		1													
Aextoxicon punctatum	1														
Cunoniaceae	1														
Unknown	5	2	2	4		1	1	1							
non-identifiable	68	41	15	26	11	9	3	5	4		3	2	1	1	
Total	119	52	41	36	16	12	8	8	8	2	4	2	1	1	1

Table 17. Wood charcoal fragments with taphonomy markers from U2, Cueva de los Catalanes. V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse.

Taxa	**V**	**V+C**	**SC**	**C**	**V+SC**	**I**	**C+SC**	**H**	**V+C+ SC**
Nothofagus sp.	9								
Myrtaceae A	4		1	1					
Cunoniaceae	4								
Drimys winteri	1			1				1	
Cryptocarya alba	1	2							
Schinus sp.	1	1		1					
Buddleja sp.	1								
Monocot	2								
Fabaceae	1								
Lithrea caustica	1								
Peumus boldus	1								
Persea lingue	1								
Ribes sp.								1	
Unknown	4		1						
non-identifiable	92	21	17	11	4	3	2		1
Total	123	24	19	14	4	3	2	2	1

Table 18. Archaeobotanical data from charred seeds (X) and micro remains analysis (0), references: Roa *et al.* 2021, Roa *et al.* 2024 and Godoy-Aguirre, 2017. Taxonomical nomenclature as presented by Roa *et al.* 2024 and Godoy-Aguirre 2017.

HERBACEOUS TAXA	Family	Identified taxa	ECP	LCP	HP
	Amaranthaceae	Chenopodioideae	x	x	
		Chenopodium quinoa	x	x	x
		Chenopodium quinoa var *quinoa*	x	x	x
		D. ambroisoides/C. album			x
	Asteraceae	Asteraceae	x		X
		Madia sativa	x	X	
	Brassicaceae	cf. Brassicaceae	x	X	
	Cyperaceae	*Schoenoplectus* sp.		x	x
	Fabaceae	Fabaceae	x	x	x
		cf. *Medicago* sp.			x
		Phaseolus vulgaris	X0	x	
	Gunneraceae	cf. *Gunnera* sp.	0		
	Oxalidaceae	cf. *Oxalis* sp.		x	
	Poaceae	Poaceae	X0	x	X0
		Zea mays		x	
		cf. *Zea mays*	X0		
		Triticum aestivum L.			x
	Polygonaceae	cf. *Persicaria hydropiperoides*		x	x
		Polygonaceae	x	x	x
		Rumex sp.			x
	Ranunculaceae	Ranunculaceae		x	
	Rosaceae	*Rubus* sp.			x
		cf. Rubus sp.		x	
	Solanaceae	*Capsicum* sp.		x	
		cf. Solanaceae			x
		cf. *Nicotiana* sp.		0	
WOODY TAXA	Anacardiaceae	Anacardiaceae	X	x	
	Elaeocarpaceae	*Aristotelia chilensis*	X0	X	X
	Fabaceae	cf. *Sophora* sp.		x	
		Acacia dealbata			x
	Lauraceae	*Cryptocarya alba*	x	X	X
	Nothofagaceae	*Nothofagus* sp.		x	
	Proteaceae	cf. *Gevuina avellana*	x	x	

Table 18. El Arenal-1, details of sample's weight according to excavation unit and provenience.

Unit	Context	Sample	Layer	Flotation Samples				Excavation Samples
				>4mm	4-2 mm	<2mm	Vol. (L)	
TP2	C-10	S-30	III					-
TP4	C-6	S-201	-					2.62
TP5	C-15	S-43	III					0.89
TP6	C-21	S-57	III					4.39
	C-29	S-77	III					1.48
	C-30	S-82	IV					6.1
	C-45	S-128	IV					1.42
TP7	C-20	S-226	II		0.02	0.01	2.05	
	C-21	S-227	II		0.07	0.02	2.8	
		S-58	II					0.64
	C-26	S-228	II	0.38	0.54	0.3	3.7	
		S-62	II					1.96
	C-33	S-73	II					2.06
	C-32	S-97	III					0.86
		S-113	III					0.3
		S-229	III	0.17	0.47	0.74	2.8	
	C-35	S-93	III					0.15
	C-46	S-120	IV					3.99
	C-46	S-230	IV	1.14	1.46	0.91	2.3	
	C-50	S-137	V					3.59
	C-51	S-160	V					8.27
	C-51	S-231	V	0.03	0.25	0.16	2.2	
TP8	C-34	S-88	II					0.96
	-	S-233	II		0.04	0.02	1.5	
	C-36	S-106	III					4.4
		S-124	III					3.82
		S-142	III					4.71
		S-154	III					3.89
	-	S-235	III	0.49	0.1	0.07	1.2	
	-	S-239	III	0.22	0.72	0.45	1.9	
	C-52	S-181	IV					0.72
		S-188	IV					0.73
		S-192	IV					0.41
	-	S-237	IV	1.54	0.58	0.33	2.0	
	-	S-241	V	0.69	0.16	0.13	2.3	
TP9	C-46	S-129	II					1.49
	C-48	S-150	III					0.47
	C-69	S-203	III					2.36
	C-53	S-180	IV					1.86
	C-59	S-193	IV					2.29
	C-63	S-200	V					0.7
	C-65	S-218	V					6.52
	C-66	S-223	V					3.59
	C-67	S-244	V					2.74

Table 20. Details of the ^{14}C dates for El Arenal-1. The calibration was done in OxCal 4.4 using the SHCal20 calibration curve.

Sample	Unit and Layer	Lab Code	Date	±	Modelled (CE)		References
					from_95.4	to_95.4	
Chicken bone	-	NZA26115	622	35	1317	1415	Storey *et al.* 2013
Stem	TP7, LV C-51	WK50049	614	21	1332	1425	Buhring *et al.* 2024
Chicken bone	-	NZA28271	510	30	1410	1450	Storey *et al*. 2013
Chicken bone	-	NZA28272	503	30	1425	1460	Storey *et al.* 2013
Stem	TP7, LII, C-21	WK50051	428	21	1451	1496	Buhring *et al.* 2024
Zea mays	TP7, LV, C-50	WK50050	412	21	1457	1512	Buhring *et al*. 2024
Monocot tissue	TP7, LIII, C-32	WK50048	353	21	1469	1590	Buhring *et al*. 2024

Table 21. Wood charcoal fragments with taphonomy markers from El Arenal-1. V: vitrification, C: radial cracks, H: hyphae, I: infillings, SC: structural collapse, XI: xylophage insect.

Taxa	V	V+C	I	C	SC	H	V+H	V+I	C+I	H+I	XI	SC+I	C+H	V+XI	V+SC+I
Myrtaceae B	46		3	3		4	2							1	
Myrtaceae A	7				1		2								
Peumus boldus	1	1	1		2						1				
Cunoniaceae	3						1								
Persea lingue			1	1					1						
Ribes sp.	1					1									
Cryptocarya alba	1														
Nothofagus sp.	1														
Unknown	19			1	4		1					1			
non-identifiable	293	29	23	14	9	6	2	8	1	1			1		1
Total	372	30	28	19	16	11	8	8	2	1	1	1	1	1	1

Table 22. Archaeobotanical data from El Arenal, counts represent charred seeds. References: Roa 2019 (results from 2018), Silva 2010 (results from 2003-2007 results). Taxonomical nomenclature copied as presented by both authors.

Taxa Type	Family	Identified taxa	2018 Layer				2003-2007
			II	III	IV	V	
Herbaceous Taxa	Amaranthaceae	cf. Chenopodioideae	1				
		Chenopodium sp.	4		2	3	
		cf. *Chenopodium sp.*	1	1	1	1	
		Chenopodium quinoa	12	45	26	12	263
		cf. *Chenopodium quinoa*			1	4	
	Asteraceae	*Madia sativa* A			2		
		Cynara sp.					34
	Poaceae	*Bromus* sp.		1	1		
		cf. *Bromus*			1		
		Poaceae	1	5	15	3	53
		cf. Poaceae	11	2			
		Zea mays					5
		cf. *Zea mays*	6	3	1	3	
	Portulacaceae	*Portulaca oleraceae*					64
	Rosaceae	cf. *Fragaria chiloensis*	1				
		Rubus sp.		4	3	1	22
		cf. *Rubus* sp.	1				
	Rubiaceae	cf. Rubiaceae		6			
	Typhaceae	*Typha angustifolia*					58
Woody Taxa	Elaeocarpaceae	*Aristotelia chilensis*		1	1		
	Ericaceae	cf. *Gaultheria* sp.		2			
	Lauraceae	*Cryptocarya alba*					7

Table 23. Summary of identified Woody taxa per site (Mocha Island= P5 P29 and P31; CC= Cueva de los Catalanes and EA= El Arenal-1) and their main ethnobotanical uses (E= edible, M= medicinal, D=dye, C= ceremonial/ritual, W= good wood, S= shampoo). Ethnobotanic references: Bragg *et al.* 1986, Cordero *et. al* 2017, Godoy 2008, Gumucio 1999, Hoffman 2005, León-Lobos *et al.* 2022, Wilhelm de Moësbach 1992, Montes & Wilkomirisky 1987, Muñoz *et al.* 1981, Pardo & Pizarro 2016, Rodríguez *et al.* 1983, Smith-Ramírez 1995 and Villagrán 1998).

Class / Family	Identified taxon	P5	P29	P31	CC	EA	Uses
Taxodiaceae	*Aextoxicon punctatum*	X	X	X	X	X	W, D
Anacardiaceae	Anacardiaceae	X		X			E, M
	Lithraea caustica				X	X	W
	Schinus sp.	X			X	X	E
Araliaceae	*Raukaua* sp.	X		X			M
Asteraceae	Asteraceae	X	X	X			M
Berberidaceae	*Berberis* sp.				X	X	E,
Celastraceae	*Maytenus* sp.	X	X	X	X	X	E, M
Cunoniaceae	Cunoniaceae	X	X	X	X	X	M, D, W
Elaeocarpaceae	*Aristotelia chilensis*	X	X	X	X	X	E, D
	Crinodendron sp.	X					M
	Eleocarpaceae	X					E, M
Ericaceae	Ericaceae	X	X	X			E
Escalloniaceae	*Escallonia* sp.	X		X	X		D
Fabaceae	Fabaceae	X		X	X	X	M
Grossulariaceae	*Ribes* sp.	X	X	X	X	X	E
Lauraceae	Lauraceae	X		X		X	E, M
	Cryptocarya alba	X			X	X	E
	Persea lingue	X			X	X	W
Liliopsida	Liliopsida	X	X		X	X	E
Monimiaceae	*Laurelia/Laureliopsis*	X	X	X	X	X	M, C
	Peumus boldus	X	X	X	X	X	E, M
Myrtaceae	Myrtaceae A	X	X	X	X	X	E
	Myrtaceae B	X	X		X	X	E
Nothofagaceae	*Nothofagus* sp.	X	X		X	X	E, D
Onagraceae	*Fuchsia magellanica*	X	X	X		X	E, M
Pinopsida	Pinopsida		X	X		X	E
Poaceae	*Chusquea* sp.				X		E
Polygonaceae	Polygonaceae	X		X			E, D
Proteaceae	Proteaceae	X		X	X	X	E, D
Quillajaceae	*Quillaja saponaria*		X		X	X	S
Rosaceae	Rosaceae	X		X			E, M
Salicaceae	*Azara* sp.	X	X				M
	Salix sp.				X		M
Scrophulariaceae	*Buddleja* sp.	X	X	X	X	X	M
Verbenaceae	Verbenaceae	X	X	X			E, M
Vitaceae	*Cissus striata*	X		X			E, D
Winteraceae	*Drimys winteri*		X	X	X	X	E, C

Table 24. Archaeobotanical data from Southern Chile Archaeological sites according to taxa and Period. Symbols: x= wood charcoal; ○= carpological remains; ●= wood charcoal and carpological remains. *In the current taxonomy *Laurelia sp*. is monotypic (*Laurelia philippiana* changed to *Laureliopsis philippiana*), and *Pseudopanax* changed to *Raukaua* (Rodríguez *et al.* 2018).

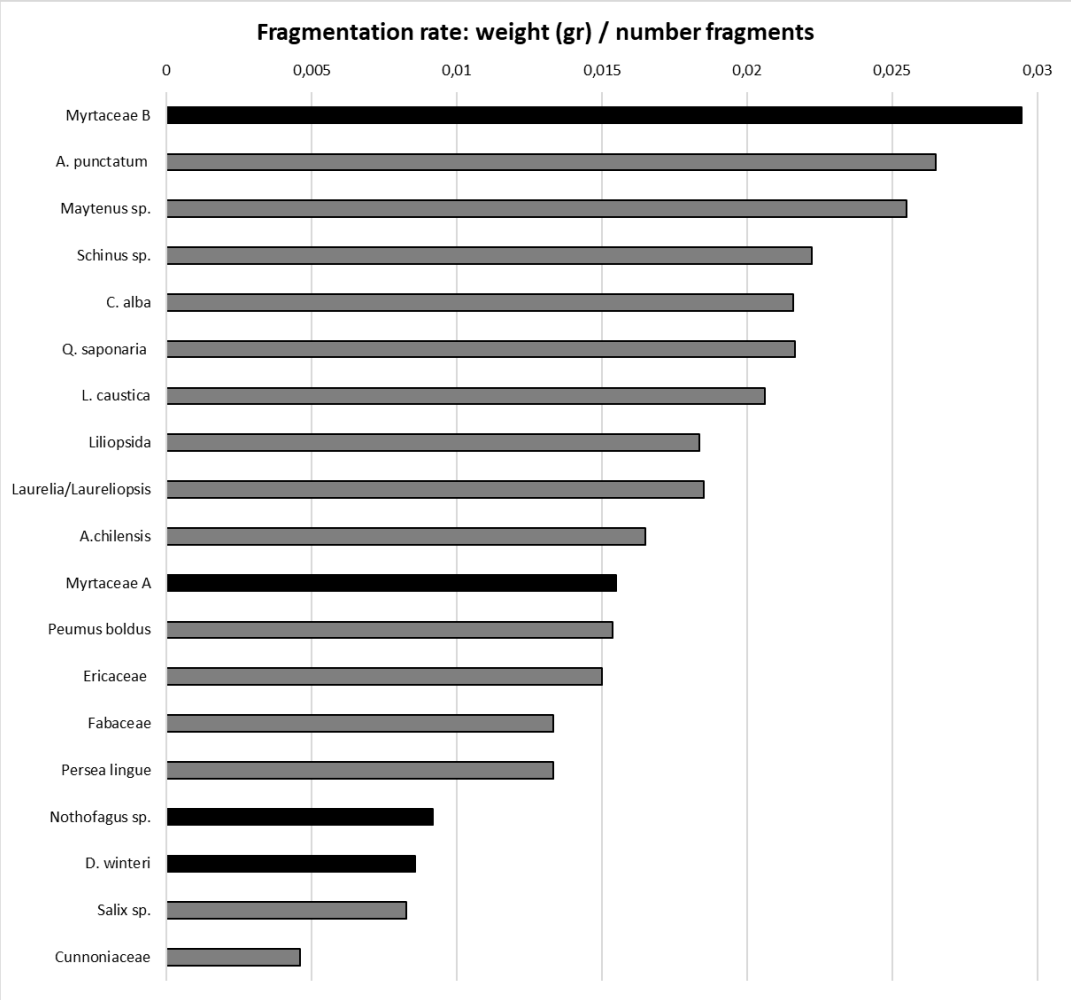
Tree taxa	AP	ECP	LCP	HP	Sites (abbreviations)
Aextoxicon punctatum	●	●	X	X	JMC-1[1], Marifilo-1[2], Mocha I.[7], PU-132[11], PU-135[11], CDLC[14], FL[14]
Amomortus luma				○	CIM
Araucaria araucana			○	○	CFSS[13]; CI[15]; CHR[16]
Cunoniaceae	X		X		Marifilo-1[2]
Cryptocarya alba		●	●	●	Mocha I.[4] EA-1[8], PU-165[9], CDLC[14], CHR[16]
Drimys winteri		○	●	X	JMC-1[1], Mocha I.[4,7], CDLC[14]
cf. *Drimys winteri*	X				Marifilo-1[2],
Eucryphia cordifolia			X		Marifilo-1[2],
Gevuina avellana		X	●	○	JMC-1[1], Marifilo-1[2], Mocha I.[4]; CIM[17]
Gymnosperm			X		Marifilo-1[2]
Lauraceae			X		Marifilo-1[2]
Laurelia sp.*	X	X	X		JMC-1[1], Marifilo-1[2]
Maytenus boaria	X		X	X	Marifilo-1[2,] IM[19]
Myrtaceae	X	X	X	X	Marifilo-1[2], PU-165[11], Pucón[11], IM[19]
Nothofagus cf. *obliqua*			X		LU-34[11], PU-87[11], Pucon[3]
Nothofagus deciduous-type	X		X		Marifilo-1[2]
Nothofagus evergreen-type			X		Marifilo-1[2]
Nothofagus sp.	X	X	●	X	Marifilo-1[2], Pu-Lu[11], Pucón[11], Mocha I.[7], CDLC[14]
Ovidia pillo-pillo	X				Marifilo-1[2]
Persea lingue		X	X	●	Marifilo-1[2], Mocha I.[7], CDLC[14]; CIM[17]
cf. *Persea lingue*	X		X		Marifilo-1[2], PU-87[11], PU-165[11], Pucon[11]
Peumus boldus	X	X	●	X	Marifilo-1[2], Mocha I.[7]
cf. *Peumus boldus*		X			JMC-1[1]
Proteaceae	X	X	X		JMC-1[1], Marifilo-1[2], PU-166[11]
Prumnopitys andina			○		CI[15]
cf. *Saxegothaea conspicua*				○	CIM[17]
Sophora microphila	X				Marifilo-1[2]
Schinus polygamus				X	IM[19]

Table 24 (continuation). Archaeobotanical data from Southern Chile Archaeological sites according to taxa and Period. Symbols: x= wood charcoal; ○= carpological remains; ●= wood charcoal and carpological remains.

Shrubs and vines	AP	ECP	LCP	HP	Sites (abbreviations)
Aristotelia chilensis	X	●	●	○	JMC-1[1], Marifilo-1[2], Mocha I.[4], CA-17[8], Pu-Lu[9], Pucón[11], CDLC[14]; CIM[17]
cf. *Berberis* sp.		X			JMC-1[1]
Berberis sp.	X		X		Marifilo-1[2], CDLC[14]
Boquila trifoliata		○			JMC-1[1]
Buddleja globosa	X	○	X	○	JMC-1[1], Marifilo-1[2], Mocha I.[7], CDLC[14], CIM[17]
Colletia sp. (type)	X				Marifilo-1[2]
Escallonia purvurulenta	X		X		Marifilo-1[2]
cf. Ericaceae	X				Marifilo-1[2]
Monocotyledoneae	X	X	X	X	JMC-1[1], Marifilo-1[2], PU-87[11], PU-165[11], Pucon[11], CDLC[14]
Muehlenbeckia hastulata		○	●	○	JMC-1[1], Mocha I.[4,7], CA-17[8]; FL[14]; CIM[17]; CHR[16]
Luzuriaga radicans		○			FL[14]
*Pseudopanax laetevirens**		○	X		Mocha I. [7]; FL[14]
*Pseudopanax valdiviensis**		○			FL[14]
Ribes sp.		○	X		Mocha I. [7]; FL[14]
Typha angustifolia			○		CA-17[8]
Ugni molinae		○		○	JMC-11; CIM[17]
Ugni sp.			○		Mocha I.[4]
Viola rubella		○			FL[14]
Unidentified vine / liana			X		PU-87[11], PU-165[11], Pucon[11]

*Site´s abbreviations and references: JMC-1[1]: Villa José Miguel Carrera (Mera & Munita 2021); Marifilo-1[2] (Lehnebach *et al.* 2008; Mera and García 2004); Mocha I.[4] (Roa *et al.* 2018); Mocha I.[6] (Sánchez *et al.* 2004), CA-17[8]: Cañete-7, EA-1[8]: El Arenal-1, SM-30[8]: Santa María-30 (Silva 2010); PU-165[9]: Purén-165 (Silva 2014), LU-6[9]: Lumaco-6[9] (Dillehay & Saavedra 2014); PU[11]: Puren, LU[11]: Lumaco, and Pucón[11] (Solari 2014); V. W-10[12]: Villarica W-10 (Adán & Mera 2011), CFSS[13]: Casa Fuerte Santa Silvia (Rossen 2011); FL[14]: Flor del Lago -1 (Coles 2011); CI[15]: Cabeza de Indio (Toro 2010); CHR[16]: Central Hidroeléctrica Ralco (Cáceres et al. 2005); CIM[17]: Castillo Isla Mancera and MN: Misión de Niebla (Silva et al. 2020); EFSC[18]: Ex-Fundo Santa Cecilia (Adán 2014), IM[19]: Isla Mancera (Soria-Galvarro 2022).

Figure 2. Fragmentation rate from identified taxa in Cueva de los Catalanes, 2018 analysis (bars in black correspond to taxa with over 50 fragments, only ones considered in discussion). A higher value indicates bigger fragments, and low value indicates smaller charcoal fragments.



APPENDIX B:

DESCRIPTIONS OF IDENTIFIED SPECIES

This section is not intended as a key of identification, proper anatomy descriptions can be found in the literature (see table below for References: R= Rancusi, Nishida and Nishida 1987; W= Wagemann 1949; T= Tortorelli 2000; S= Solari 1993; C= Caruso-Fermé 2012; F= Franch Bach *et al.* 2022; A= Andreoni 2014; P= Piqué i Huerta 1999; M= Miles 1978). Apart from the observed features, I included certain recurring observations that were considered later when assigning taxonomical identification.

Class / Family	**Identified taxon**	**References**								
		R	**W**	**T**	**S**	**C**	**F**	**A**	**P**	**M**
Aextoxicaceae	*Aextoxicon punctatum*	X	X		X					x
Anacardiaceae	Anacardiaceae		X		X					X
	Lithraea caustica		X		X					
	Schinus sp.		X	X	X		X	X		
Araliaceae	*Raukaua* sp.	X	X		X					
Asteraceae	Asteraceae		X	X	X		X	X	X	
Berberidaceae	*Berberis* sp.	X			X	X	X	X	X	
Celastraceae	*Maytenus* sp.	X	X	X	X	X	X	X	X	
Cunoniaceae	Cunoniaceae	X	X		X					x
Elaeocarpaceae	*Aristotelia chilensis*	X			X					
	Crinodendron sp.	X	X		X					
	Eleocarpaceae	X			X					
Ericaceae	Ericaceae				X	X	X			
Escalloniaceae	*Escallonia* sp.		X		X	X		X		
Fabaceae	Fabaceae		X	X	X	X	X	X		
Grossulariaceae	*Ribes* sp.				X	X	X		X	
Lauraceae	Lauraceae	X	X		X					
	Cryptocarya alba	X	X		X			X		
	Persea lingue	X	X		X					x
Liliopsida	Liliopsida									
Monimiaceae	*Laurelia/Laureliopsis*	X	X		X					x
	Peumus boldus	X	X		X					
Myrtaceae	Myrtaceae A	X	X	X	X			X		
	Myrtaceae B	X	X		X					
Nothofagaceae	*Nothofagus* sp.	X	X	X	X	X	X	X	X	x
Onagraceae	*Fuchsia magellanica*				X					
Pinopsida	Pinopsida	X	X	X	X	X				x
Poaceae	*Chusquea* sp.				X	X				
Polygonaceae	Polygonaceae				X					
Proteaceae	Proteaceae	X	X	X	X	X	X		X	
Quillajaceae	*Quillaja saponaria*	X	X		X					
Rosaceae	Rosaceae	X	X		X					
Salicaceae	*Azara* sp.	X	X		X					
	Salix sp.	X	X	X	X					
Scrophulariaceae	*Buddleja* sp.				X					
Verbenaceae	Verbenaceae	X			X			X		
Vitaceae	*Cissus striata*				X					
Winteraceae	*Drimys winteri*	X	X	X	X		X		X	x

1. Aextoxicon punctatum Ruiz & Pav**.,** Aextoxicaceae

Evergreen tree and only species of the Aextoxicaceae family. Common name of *tique* or *olivillo*, which translates as little olive tree but it not taxonomically related (the ripe fruit resembles an olive, hence the name). The wood is appreciated for construction, and the bark can be used as dye. It is a common component of the lauriphyllous forest, and since it is a shade tolerant species it can form part of old growth forest formations.

Observed anatomical features:

Transversal Plane: diffuse porous wood composed of vessel and wood fibres of slightly polygonal appearance. Some small pores can blend easily into the wood fibres.

Longitudinal plane: Vessel elements show scalariform intravessel pitting and scalariform perforation plaques (≥ 40 bars). Although according to the literature the species can show up to 100 bars in the perforation plates, in wood charcoal the bars were usually observed broken and it was difficult to count them. Presence of uniseriate rays and heterogenous (type I of Kribs according to Rancusi *et al.* 1987)

2. Anacardiaceae

Sclerophyllous family of woody plants that encompasses 3 genera, but only two naturally distributed in Southern Chile: *Lithrea* and *Schinus*. In the fragments identified to family level there were not enough features to assign them to a genus.

Observed anatomical features

Transversal Plane: diffuse porous wood, vessels are usually grouped in a radial direction (groups of 2 to 6 pores). Growing rings are only visible due to the compression of woody fibres.

Longitudinal planes: Vessel elements show simple punctuation and simple perforation plates, rays are short and very numerous.

3. Lithrea caustica (Molina) Hook. & Arn., Anacardiaceae

Only species of the genus, habitus of a tree with a wide distribution (30°-40° S, from sea level to 1800 m ASL according to Rundell 1981), and it can grow under different ecological conditions.

Observed anatomical features:

Transversal Plane: diffuse porous wood composed of vessels and wood fibres, the vessels elements have a semi oval shape, usually found in groups of 2 or 4 vessels following a radial direction.

Longitudinal planes: Vessel elements show simple punctuation and simple perforation plates, but according to Wageman sometimes they can also be reticulate plates (1949). Spiral thickness has been reported in the vessel elements, although not observed as frequently as in *Schinus* sp. Rays are uniseriate, biseriate and triseriate, they are frequent, and they show up to 16 cells of height.

4. *Schinus* sp., Anacardiaceae

There are 8 species of trees and shrubs in the Schinus genus (four native and four endemics to Chile). In ecological terms, four species are found in Southern Chile: *S. montanus, S. patagonicus* var*. patagonicus, S. patagonicus* var. *crenuloides,* and S. polygamus. Among these species, there are proper anatomical descriptions and references for *S. polygamus* (Wageman 1949), but unfortunately, the reference collection does not contain all the species of the genus.

Observed anatomical features:

Transversal Plane: wood composed of vessels and wood fibres. Vessel elements are found in groups of 2 or 4 forming a tangential band arrangement. This arrangement is described as ulmiform by Wageman (*ulmiforme*), that according to the IAWA corresponds to wavy tangential bands tending to form a diagonal pattern (Features 6 and 7, IAWA 1989)

Longitudinal planes: Vessel elements show simple punctuation and simple perforation plates, but according to Wageman sometimes they can also be reticulate plates (1949). Spiral thickness has been reported in the vessel elements, and frequently observed in the analysed fragments. Rays are uniseriate, biseriate and triseriate, they are frequent, and they show up to 16 cells of height. Sometimes rays can preset intercellular canals also known as gum ducts.

5. *Raukaua* sp., Araliaceae

Only native genus of the Araliaceae family in Chile (formerly known as *Pseudopanax*), has only two species: *Raukaua laetevirens* (Gay) Frodin (native small tree or shrub), and *Raukaua valdiviensis* (Gay) Frodin (endemic climbing shrub). The identified fragments were only assigned to genus level because there are no anatomical descriptions of *R. valdiviensis* and unfortunately is not part of the reference collection.

Observed anatomical features:

Transversal Plane: Growth ring visible by the compressed fibres and smaller size of vessels. Diffuse wood with groups of pores arranged in radial direction: usually from 6 to 8 according to Wageman (1949), and 2 to 5 according to Rancussi *at al.* (1987). Vessel or pores tend to show angular shapes.

Longitudinal planes: Perforation plates of vessels are simple, and punctuations opposite to scalariform. Rays are usually heterogeneous (Type II A of Kribs), They are mostly multiseriate (2-4 cells width), and there are few uniseriate.

6. Asteraceae

Although the Asteraceae family is widely known for the herbaceous species and weeds, in Southern Chile there are more than 150 woody species, representing over 20 genera. Most of the native and endemic Asteraceae specimens are shrub and other minor woody plants (so not many anatomical descriptions are available), and there is just one tree species in Southern Chile: *Dasyphyllum diacanthoides*. Since our reference collection does not have all the genera, the taxonomical identification was only conducted to family level, although I'm certain that the fragments do not correspond to *D. diacanthoides* but to shrubs.

Observed anatomical features:

Transversal Plane: diffuse porous wood, with small vessel elements (sometimes hardly distinguishable). Rays' width is variable, between 1 to 6 cell rows.

Longitudinal planes: rays are heterogenous, usually numerous. Spiral thickness has been reported for *Baccharis* and *Dasyphyllum* (Rancusi et al. 1987, Solari 1993).

7. *Berberis* sp., Berberidaceae

This is the only native genus of the Berberidaceae family and includes native and endemic shrubs and small trees. In Southern Chile, there are 15 species, and most of them have edible berries. Based on the field experience during the modern reference collection sampling, some species have a hard wood, and according to ethnographic data from Patagonia, the wood of Berberis was used as handle for spears (Caruso-Ferme 2021).

Observed anatomical features:

Transversal Plane: Vessel elements found in clusters, sometimes forming ulmiform bands. Solitary pores are also present, but less frequently. Growth rings sometimes distinguishable by the compress fibres.

Longitudinal planes: Perforation plates simple, intravessel pitting alternate, and spiral thickness very notorious. Rays are exclusively multiseriate (between 4 to 14 cells wide).

***8. Maytenus* sp.**, Celastraceae

Only genus of woody plants part of the Celastraceae family. There are 4 native species found in Southern Chile, two of them correspond to trees (*Maytenus boaria* and *Maytenus magellanica*) and the other two to shrubs (*Maytenus disticha* and *Maytenus chubutensis*).

Observed anatomical features:

Transversal Plane: wood diffuse porous, vessel elements mostly solitary, and small.

Longitudinal planes: Simple perforation plates, and intervessel pitting alternate. Spiral thickness observed and reported frequently. Rays are numerous, uniseriate and multiseriate. While uniseriate rays are formed by procumbent cells (and they are short, usually 1 to 3 cells of height), multiseriate rays are heterogenous and very long (over 30 cells of height).

9. Cunoniaceae

Family of trees composed by native three genera: *Caldcluvia, Weinmannia*, and *Eucryphia*. The first two genera have only one species each: *Caldcluvia paniculata* and *Weinmannia trichosperma* Cav. The Eucryphia genus used to be considered as its own family Eucryphiaceae, but currently the two species *Eucryphia cordifolia* Cav., and *Eucryphia glutinosa* (Poepp. & Endl.) Baill. are part of the Cunoniaceae family.

In anatomical terms, Caldcluvia and Weinmannia are similar, and it has been proposed by Rancusi and collaborators (1987) that differentiation among them can be achieved using a quantitative approach (vessel frequency, number of bars per scalariform perforation, ratio of biseriate and triseriate rays), which is not frequently possible when working with small charcoal fragments. Based on my personal experience, *Eucryphia* also share many of these main features, so for caution they were all assigned to family level.

Observed anatomical features:

Transversal Plane: diffuse porous wood, vessel element are small (around 50 µm of diameter) and numerous. They are mostly solitary, and they have an angular shape. Growth rings are sometimes visible due to the presence of terminal parenchyma (Wageman 1949), and smaller size of vessels.

Longitudinal planes: Perforation plates scalariform in *Caldcluvia* and *Weinmannia*, and simple and scalariform in *Eucryphia* (but often bars are broken and hard to observe). Rays are numerous and heterogenous in all genera. They can be uniseriate, biseriate, triseriate, and multiseriate in *Eucryphia.*

10. Eleocarpaceae

The family has two genera and 3 species: *Aristotelia chilensis* (Molina) Stuntz, *Crinodendron hookerianum* Gay, and *Crinodendron patagua* Molina. All of them are trees found in Southern Chile.

Fragments identified to family level presented common features to both species.

Observed anatomical features:

Transversal Plane: diffuse porous wood, with clear growth rings. Vessel elements commonly found in radial groups (up to 10 pores). Vessel walls are thin, and they tend to show an angular shape.

Longitudinal planes: simple perforation plates, no presence of spiral thickness. Uniseriate to multiseriate rays, most of them are heterogenous (type II Kribs).

11. *Aristotelia chilensis* (Molina) Stuntz, Eleocarpacae

Only native species of the genus. This tree, commonly known as *maqui* or *klon*, is a very common species that can also grow as bushes, forming a secondary formation called *macal* or *macales*. The berry is small and edible, and recently branded as a “super berry” because of the hight content of antioxidants. Because in commercial terms is not a “good timber”, there are less descriptions in comparison to other tree species. Based on my experience and from conversations with other charcoal analysts, some anatomical features can vary significantly (number and size of pores, frequency of multiseriate rays). This could be related to specific growing conditions since is a really fast-growing species.

Observed anatomical features:

Transversal Plane: diffuse porous wood, vessels usually found in clusters or groups following a radial direction. Vessel elements show an angular section. Growth rings are distinguishable by the flattening of the fibres and reduction of pore size.

Longitudinal planes: perforation plates are simple. Uniseriate rays are homogenous formed by upright cells, while multiseriate rays are heterogenous and presenting upright cells in the ends.

12. *Crinodendron* sp., Eleocarpaceae

The genus has two tree species, both endemic and found in Southern Chile. Anatomical descriptions are common for *Crinodendron patagua* Molia (common name of *patagua*), but no for *Crinodendron hookerianum* Gay.

Observed anatomical features:

Transversal Plane: diffuse porous wood, vessels usually found in clusters or groups following a radial direction. Vessel elements show an angular outline. Growth rings are distinguishable by the flattening of the fibres and reduction of pore size (especially in solitary pores).

Longitudinal planes: perforation plates are simple. Uniseriate rays are homogenous formed by upright cells and they are more numerous than biseriate and triseriate rays.

13. Ericaceae

Family of shrubs and subshrub that includes 3 genera: *Gaultheria, Empetrum,* and *Lebetanthus*. These last two genera are represented just by one native species each, and they used to be considered as different families: Empetraceae y Epacridaceae respectively. There are 15 species in the *Gaultheria* genus, which used to be known as *Pernettya* (so older descriptions can be found under different names).

The fragments identified as Ericaceae show characteristic features of the *Gaultheria* genus. Since no modern samples from the other genus were obtained (only studied using publications such as Solari 1993 and Caruso Fermé 2012), for caution it was assigned to family level. More samples of the genus are needed to evaluate if it can be identified as *Gaultheria* sp.

Observed anatomical features

Transversal Plane: diffuse porous wood, with abundant very small vessel elements (around 20 μm of diameter). Growth rings are not very distinguishable, but rays are easily noticeable.

Longitudinal planes: perforation plates can be simple or scalariform. Spiral thickness is frequent and noticeable. The uniseriate rays are short and composed of upright cells, multiseriate rays are big (3 to 9 cells of width and sometimes over 1 mm of height).

14. Escallonia sp., Escalloniaceae

Genus of 20 native and endemic species including trees, small trees and shrubs. In some nomenclatures the genus is under the Saxifragaceae Family, but currently is considered its own family (along with other two genera: Valdivia and Tribeles). Previous descriptions have been focused on the trees of the genus, commonly known as *lun*: *Escallonia revoluta* (Ruiz & Pav.) Pers., and *Escallonia myrtoidea* Bertero ex DC (lun) (formerly known as *Escallonia arguta* C. Presl). The wood is considered of inferior quality and fragile (prone to breaking according to Kausel 1953).

Observed anatomical features

Transversal Plane: diffuse porous wood, vessel elements are mostly solitary, small (30-45 μm of diameter) and of polygonal shape. Growth rings are visible due to the flattening of the woody fibres and decrease of vessel size.

Longitudinal planes: perforation plates are scalariform in most species and reticulate in *Escallonia illinita, Escallonia serrata, Escallonia rubra (*Solari 1993). Spiral thickness is thin and easily observed. Rays are heterogenous, and they can bi uniseriate, biseriate and triseriate and multiseriate (up to four rows of cells has been reported for *Escallonia myrtoidea*, Wageman 1947, and up to 5 cells of width in *Escallonia* serrata according to Solari, 1993).

15. Fabaceae

This family has 8 native genera found in Southern Chile, representing more than 20 species of endemic and native trees, shrubs and subshrubs. Because our reference collection is not representative of the diversity of the family, for caution the fragments were identified to family level.

Observed anatomical features

Transversal Plane: vessel elements are usually found solitary or in clusters of 2 to 4 pores. Parenchyma is notorious, located around the vessel (Axial parenchyma vasicentric, feature 79 of IAWA). Vessel elements have different sizes (usually one big is clustered with smaller ones), and they show a circular shape.

Longitudinal planes: perforation plates are simple, vessel pits are bordered and sometimes scalariform. Spiral thickness observed in the genera *Acacia*, *Sophora*, and *Otholobium*. Rays are homogenous and multiseriate, and short (20-35 cells of height). Some species show uniseriate rays, like *Sophora cassioides* (Phil.) Sparre (Solari, 1993).

16. *Ribes* sp., Grossulariaceae:

Ribes is the only native genus of the Grossulariaceae family in Southern Chile. There are 9 species of shrubs (native and endemic), commonly known as *parilla*. Under some taxonomies the genus used to be considered under the Saxifragaceae family. They have edible berries.

Observed anatomical features

Transversal Plane: semi-diffuse porous wood, growth rings are visible due to a continuous band of pores located at the end of each growth ring. Vessel elements are also found forming tangential bands. Rays are wide and very visible.

Longitudinal planes: woody tissue formed of tracheid and libriform fibres. Punctuation plates are scalariform. Rays are uniseriate (formed of upright cells), and multiseriate (4-12 cells of width).

16. Lauraceae

This family is composed of four tree species: *Beilschmiedia miersii* (Gay) Kosterm., *Beilschmiedia berteroana* (Gay) Kosterm., *Cryptocarya alba* (Molina) Looser, and *Persea lingue* (Ruiz & Pav.) Nees. These last three species are found in Southern Chile, *Persea lingue* is the only classified as native, the other three are endemic.

Unfortunately, the reference collection does not have samples of *Beilschmiedia* (protected genus because of vulnerable status, only studied using published material), so fragments of uncertain ascription were classified at family level as Lauraceae.

Observed anatomical features

Transversal Plane: diffuse porous wood, vessel elements show an oval shape, and they have a small diameter (around 50 μm). They are either solitary or forming short bands in a radial direction (2-3 pores).

Longitudinal planes: perforation plates are simple, and intervessel pitting mostly alternate. Rays are heterogenous type II of Kribs in all the species, they are uniseriate, biseriate and triseriate, and they are short. A characteristic feature of the family are oil cells, usually found in the erect cells of the rays, they are larger cells, and they look “fatty”.

17. *Cryptocarya alba* (Molina) Looser., Lauraceae

Only species of the genus, commonly known as *peumo* and named in English as the “Chilean acorn”. This tree is a common component of the sclerophyllous

forest, indicative of old succession state. The fruit can be eaten after processing (either cooked of as flour, and there are references saying that can also be eaten after “soaking it” in the mouth, Muñoz et al. 1981) and was also used to produce an alcoholic fermented drink known as chicha.

Observed anatomical features

Transversal Plane: diffuse porous wood, vessel elements show polygonal shape, and they have a small diameter (average 50 μm). They are either solitary or forming short bands in a radial direction (2-3 pores).

Longitudinal planes: perforation plates are simple, and intervessel pitting alternate. Rays are homogenous, mostly multiseriate (3-4 cells of width), and short. While Rancusi and collaboratos (1987) mention the rays as heterogenous and very abundant, Wageman indicates they are homogenous and not numerous (1947). This can be result of different ecological growing conditions. Sometimes, multiseriate rays appear connected at the ends.

18. *Persea lingue* (Ruiz & Pav.) Nees., Lauraceae

This native tree is known as *lingue*, although is not a vulnerable species it is not an easy to find species in Southern Chile. Ecologically it can be found among the sclerophyllous or lauriphyllous forest, usually indicative of a late successional stage (shade tolerant species). The fruit is not edible (poisonous for some animals), and the wood is appreciated (Rodriguez *et al.1983*).

Observed anatomical features

Transversal Plane: diffuse porous wood, and in comparison to the other species of the Lauraceae family, *P. lingue* has bigger vessel elements (60-120 μm). The pores are mostly solitary or grouped in pairs in a radial direction. Growth rings can be distinguished by the flattening of fibres and a decrease of the pore size.

Longitudinal planes: perforation plates are simple, and some spiral thickness has been reported for the species (Rancusi 1987). Rays are heterogenous, uniseriate rays are usually composed of upright cells. Oil cells are usually found at the end of the rays.

19. Liliopsida

In taxonomical terms, the monocots are not considered proper woody plants. The main native monocots showing lignified steams belong to the Bromeliaceae and Poaceae family, and they are very frequent in Southern Chile.

Observed anatomical features: Monocots were assigned to the class level because there are not distinctive features of each family. In anatomical terms, the most distinctive feature is the vascular bundles observable in the transversal plane, which form a skull like pattern.

20. Laurelia/Laureliopsis, Monimiaceae

Laurelia sempervirens (Ruiz & Pav.) Tul. and *Laureliopsis philippiana* (Looser) Schodde used to be considered part of the Laurelia genus: *L. sempervirens and L. philippiana.* So, in older reports they are usually referred as *Laurelia* sp. More recently, based on DNA analysis, the endemic *Laurelia sempervirens* has been classified under the Atherospermataceae family. In anatomical terms, they are really similar, and the ecological information indicates that hybridisation among these two species is common (Alarcon and Donoso 2004). Both tree species are shade tolerant and usually found in the lauriphyllous forest.

Observed anatomical features

Transversal Plane: diffuse porous wood, vessel are abundant and small, evenly distributed, angular shape, mostly solitary, or grouped in pairs. Growth rings are visible due to flattening of wood fibres and decrease of pore size.

Longitudinal planes: perforation plates are scalariform and very long (up to 30 bars). Rays are heterogenous (type II of Kribs), they are uniseriate, biseriate and triseriate. Rays are usually short (up to 20 cells). Pits are scalariform.

21. Peumus boldus Molina, Monimiaceae

Endemic tree part of the sclerophyllous forest, but very common among lauriphyllous formations. Commonly known as *peumo*, has an edible fruit, and the leaves are used for medicinal infusions. It hosts a parasite shrub *Notanthera heterophylla* (Ruiz & Pav.) G. Don, known as *quintral del boldo*.

Observed anatomical features: in broad terms, *P. boldus* is very different from the other two species of the Monimiaceae family, not only anatomically but also in habitat and overall appearance.

Transversal Plane: diffuse porous wood, vessel elements usually in radial clusters (2-6 pores). Rays are easily distinguishable, since they are much wider in comparison to the other species of the family.

Longitudinal planes: perforation plates are simple; vessel elements show a sinuous position easily observable. Fine spiral thickness has been reported (Rancussi et al. 1987). Rays are multiseriate (up to 9 cells of width), and they

are commonly fractured in the archaeological charcoal. The rays are heterocellular, containing procumbent, upright and square cells.

22. Myrtaceae type A

In Southern Chile, the Myrtaceae family is composed of 8 genera and more than 20 species of native and endemic trees and shrubs. The family has a wide distribution, associated to water courses and ravines. As a subfamily group, type A includes taxa with features common to the *Luma, Myrgeugenia*, and *Ugni* genera, which apparently are classified as the Myrtoideae sub family (Patel 1995). However, Myrgeugenia is a large genus of mostly shrubs with more than 10 species, and most of the descriptions are focused on the tree species: *Myrceugenia exsucca* (DC.) O. Berg and *Myrceugenia planipes* (Hook. & Arn.) O. Berg. Based on the observation of different specimens (and assuming an accurate taxonomic identification of the reference samples), the wood anatomy show variation (sometimes resembling a type B rather than type A). Since it was not possible to study all the species (some of them not even found in the reviewed literature), I´m still no certain if *Myrceugenia* can be considered under type A.

Observed anatomical features: one of the common features of this subfamily is the presence of scalariform perforations.

Transversal Plane: diffuse porous wood, vessels are small (diameter of 30-40 µm) and abundant. Pores are mostly solitary, but sometimes small radial series of 2-3 pores are observed. Growth rings are visible due the flattening of wood fibres.

Longitudinal planes: scalariform perforation plates, and simple and scalariform are reported for the *Myrceugenia* genus (Rancussi *et al.* 1987). The wood fibres have visible bordered pits, sometimes scalariform or opposite. Rays are heterogenous, mostly uniseriate, biseriate and less frequently triseriate.

23. Myrtaceae type B:

This type includes taxa with features common to the *Amomyrtus*, *Blepharocalyx* and *Tepualia* genera. In ecological terms, and similarly to the type A, the taxa are described as hygrophilous. In relation to the wood, some species such as *Amomyrtus luma* (Molina) D. Legrand & Kausel, *Amomyrtus meli* (Phil.) D. Legrand & Kausel) are described as very hard due to a slow growing (Hoffman 2005).

Observed anatomical features

Transversal Plane: Diffuse porous wood. In comparison to the type A, Type B presents bigger vessel elements (over 50 µm), and they are exclusively solitary

and circular or slightly oval in shape. Growth rings can be visible due the reduction of pore size and more dense wood fibres.

Longitudinal planes: simple perforation plates, alternate pitting. Presence of uniseriate, biseriate and triseriate rays. Uniseriate rays are homogenous (upright cells), while bi and triseriate trays are heterogeneous (Type I to II Kribs).

24. Nothofagus sp., Nothofagaceae

The genus is the only one in the family, and considers 10 species of native and endemic trees. They are typical timber species of Southern Chile, and some species like *Nothofagus obliqua* (Mirb.) Oerst. are appreciated as firewood and charcoal *carbon* or *leña de hualle* (Wilhelm de Mösbach 1992).

Observed anatomical features: in general terms, identification to species is not easy among the *Nothofagus* genus but is frequently seen in wood charcoal analysis the categories of *Nothofagus* deciduous versus *Nothofagus* evergreen (Caruso-Fermé, 2012; Lehnebach et al., 2008). In this study, all the fragments identified as *Nothofagus* sp. show the features of the deciduous taxa.

Transversal Plane: diffuse porous wood, vessel elements are solitary or found in radial series (2-10 cells). Growth rings are visible by the flattening of wood fibres.

Longitudinal planes: perforation plates are simple, and vessel pits are scalatiform and opposite. Spiral thickness has been reported for some species such as *N. obliqua* (Rancusi *et al.* 1987). The rays are mainly biseriate and uniseriate, and rarely triseriate.

25. Fuchsia magellanica Lam., Onagraceae

Fuchsia is the only woody native genus of the Onagraceae family, with only two species: *Fuchsia lycioides* Andrews (endemic bush of the northern regions of Chile), and *Fuchsia magellanica,* native bush found in Central and Southern Chile. Commonly known as *chilco*, it is a secondary bush of fast growth. The fruit is an edible berry and trditionally used also for medicinal purposes.

Observed anatomical features

Transversal Plane: diffuse porous wood, vessel elements can be found solitary or in small clusters radial (2-3 vessels). The size of the pores is variable, according to Solari 1993, the average diameter is 30 μm in the initial wood and 80 μm in the late wood.

Longitudinal planes: perforation plates are simples, and some fine spiral thickness has been reported. Intravessel pits are abundant and big. The woody tissue is formed by tracheid fibres. Rays are either uniseriate (up to 12 cells of height) or multiseriate (up to 5 cells of width, and more than 1 mm of height).

25. Pinidae

There are eight tree and one shrub native species of conifers in Chile, comprising eight genera and only three different families (Araucariaceae, Cupressaceae, and Podocarpaceae). Considering the ecology of the different species, and the geographical location of the analysed sites it seems more probable that the identified conifers correspond the Podocarpaceae family. Unfortunately, most of the fragments identified as conifers were small (not enough features observed to support a more accurate identification), so they were assigned to a broad taxonomical category.

Observed anatomical features:

Transversal Plane: wood composed of tracheids, no presence of vase elements or resin canals. Growth rings distinctive.

Longitudinal plane: Rays exclusively uniseriate (3-5 cells of height).

26. *Chusquea* sp., Poaceae

In strictly terms, the *Chusquea* genus is a perennial herbaceous plant with lignified stems that grow as canes. In fact, some the members of the family like *Chusquea quila* Kunth are usually referred as the Chilean bamboo. The canes are considered good fuel for starting a fire.

Observed anatomical features: Macroscopic features made possible to identify this fragment to genus species and not as Liliopsida like the rest of the

monocots. In this specific fragment, rests of the node with some branches were identified. In microscopic terms, it shares the features with the other monocots: presence of vascular bundles, which form a skull like pattern.

27. Polygonaceae

There are three woody genera of the Polygonaceae family: *Chorizanthe, Muehlenbeckia* and *Polygonum,* all corresponding to native shrubs and endemic subshrubs. Because these taxa are not considered economically valuable, there are almost no published references of anatomical description. In the reference collection there is just one species *Muehlenbeckia hastulata* (Sm.) I.M. Johnst., very common in Southern and Central Chile and known as *quilo*. The fruit is an edible false drupe, traditionally used for medicinal purposes, but also as dye (Wilhelm de Mösbach 1992).

Observed anatomical features: description is based on *M. hastulata,* a shrub that shows features similar to climbing shrubs.

Transversal Plane: diffuse porous wood, vessel elements show an angular shape, and they are usually found forming radial series of 2-3 pores. The vessel elements are quite big (100 µm according to Solari 1993). Rays are easily visible.

Longitudinal plane: perforation plates are simple, presence of alternate and opposite bordered pits. Wood tissue composed of tracheid fibres. Rays are quite wide, although they can have 2 – 3 cells of width (up to five rows of cells), they are composed of upright cells, and they can have more than 2 mm of height.

28. Proteaceae

The Proteaceae family is composed of 4 genera and 6 species, five of them are 5 native trees to southern Chile, and there is just one shrub: *Orites myrtoidea* (Poepp. & Endl.) Benth. & Hook.f. ex B.D. Jacks. Among the trees, *Gevuina avellana* Molina produces edible nuts known as the Chilean hazelnuts.

Although there are descriptions for all the tree species, and they are all also represented in the reference collection, the identification as done to family level because the fragments of this taxon are usually recovered in a fragmented state (probably related to the big rays and clustered pores).

Observed anatomical features:

Transversal Plane: circular porous wood, pores are small and arranged in tangential bands. Growth rings are visible because there is a decrease in the separation between bands of pores.

Longitudinal plane: simple perforation plates and alternate to opposite pitting observed in the vessel elements. Rays are wide and very notorious (visible even under macroscopic examination). There are uniseriate rays composed of square to upright cells, and multiseriate heterogenous, up to 24 rows of cells of width.

29*. Quillaja saponaria* Molina**,** Quillajaceae

Endemic species, only representative of the family in Chilean territory, and used to be considered under the Rosaceae family. Is a sclerophyllous tree, known as *quillay* or soapbark tree in English due to the content of saponins in its bark. It has been used since pre-colonial times as detergent.

Observed anatomical features:

Transversal Plane: diffuse porous wood. Vessel solitary, of circular shape and variable size (31-106 μm according to Rancusi *et al.* 1987). Growth rings not clearly delimited (decrease of pore size).

Longitudinal plane: simple perforation plates, alternate to opposite vessel pitting. Most of the rays are multiseriate (2-4 cells rows of cells, but thin), and less frequently, uniseriate (and very short).

30. Rosaceae

In southern Chile there are three genera of woody plants of the Rosaceae family: *Kageneckia, Tetraglochin*, and *Margyricarpus*. The last two correspond to native shrub and subshrubs, while *Kageneckia* correspons to endemic trees. Most of the description are focused on the tree species: *Kageneckia angustifolia* D. Don, and *Kageneckia oblonga* Ruiz & Pav.

For caution, and since there is not publish information for all the species, identification was assigned to family level.

Observed anatomical features:

Transversal Plane: diffuse porous wood, vessel elements are small and mostly solitary or found in radial series of 2-3 pores (sometimes up to 6).

Longitudinal plane: perforation plates are simple, and vessel pitting can be alternate to opposite. Uniseriate rays are homogenous, composed by upright cells (average 8 cells of height). Multiseriate rays have usually 2-6 cells of width, they are heterogenous and up to 15 cells of height.

31. *Azara sp.,* Salicaceae

The Salicaceae family has only two native genera, all corresponding to woody species. *Azara* is the largest, with eight species of native and endemic trees and shrubs. This genus used to be considered under the Flacourtiaceae family. Most of available descriptions are for the bigger species (descried as small trees by Rodriguez *et al*. 2018), like *Azara petiolaris* (D. Don) I.M. Johnst, *Azara integrifolia* Ruiz & Pav., and *Azara lanceolata* Hook.f.

Observed anatomical features:

Transversal Plane: diffuse porous wood, vessel elements found in radial series of 2 to 20 pores, and also in clusters, forming an ulmiform pattern. Solitary pores are rare, vessel elements have an angular outline. Growth rings are visible due to fibre flattening, and by an almost continuous bands of pores in early wood.

Longitudinal plane: perforation plates are described as simple for *Azara petiolaris* (Wageman 1947), and scalariform for Azara cf. integrifolia (Solari 1993), and scalariform and simple in *A. integrifolia* and *A. lanceolate (*Rancusi *et al*. 1987). Vessel pitting is bordered. Rays are uniseriate to triseriate. Uniseriate rays are abundant and formed by upright cells, and bi to triseriate rays are thin, and not long (up to 30 cells of height).

32. *Salix humboldtiana* Willd, Salicaceae

This is the only native species of the genus *Salix*. There are four introduced species of *Salix* in Southern Chile, and according to the bibliography, hybrid of native and the exotic and *Salix babylonica* L. are naturally occurring (Rodriguez *et al.* 2018). This specie is known as "*sauce chileno* or Chilean weeping willow and has been described as a pioneer species in water saturated soils, it is frequently found borders or lakes and rivers (Parolin *et al.* 2022).

Observed anatomical features:

Transversal Plane: diffuse porous wood, pores mostly solitary but also found in pairs (radial alignment) or clusters. The outline of pores is distinctively circular (sometimes slightly oval), and size is variable (35-100 µm). Growth rings are observable due to the flattening of woody fibres.

Longitudinal plane: perforation plates are simple, vessel pitting is alternate showing hexagonal to circular borders. Rays are mostly uniseriate, heterogenous (type III Kribs), and biseriate in middle parts.

33. *Buddleja sp.,* Scrophulariaceae

The Scrophulariaceae has only two native genera in Southern Chile, *Buddleja* (woody) and *Alonsoa* (woody and herbaceous), and there are only two species

of the family: *Buddleja globosa* Hope, and *Buddleja araucana* Phil, both corresponding to shrubs.

B. globosa is a well known medicinal plant commonly called *matico* (Wilhelm de Mösbach 1992). Most of the previous descriptions are based on this species, and at the moment there are no references for *B. araucana*. So, for caution, the identification was done to the genus level.

Observed anatomical features (based on *B. globosa*):

Transversal Plane: diffuse porous wood, pores are found in tangential bands in the beginning of the growth rings, but mostly solitary at the end of them. Growth rings are visible due to the flattening of the fibres. Rays are not continuous.

Longitudinal plane: simple perforation plates, and alternate intravascular pitting. Spiral thickening observed frequently, woody tissue form by tracheid fibres. Rays are heterogeneous, uni to triseriate. Whilr uniseriate rays are very short (up to 3-4 cells of height), bi and triseriate rays are longer (up to 20 cells of height).

34. Verbenaceae

This family includes 4 woody genera of native shrubs and subshrubs in Southern Chile: *Diostea, Glandularia, Junellia*, and *Rhaphithamnus.* Among them, most available descriptions correspond to *Rhaphithamnus spinosus* (Juss.) Moldenke.

Identification was done to family level due to the missing anatomical information for most of the other native species of the family.

Observed anatomical features:

Transversal Plane: diffuse porous wood, vessel cells are small, sometimes hard to identify (20-40 μm of diameter). Pores are solitary, but also found in radial series of 2-3 cells. According to Solari (1993), in *Rhaphithamnus spinosus* scalariform perforations are more visible in the transversal plane, observable in the interior of some pores, and Rancusi and collaborators (1987) indicates same species has simple perforation plates.

Longitudinal plane: Perforation plates with up to 30 bars, but the bars are fine and difficult to identify (no bars observed in examined samples). Spiral thickness sometimes visible in vessels. Rays are uni to triseriate, homogenous.

35. *Cissus striata* Ruiz & Pav., Vitaceae

Cissus striata is the only native species and of the Vitaceae family. It is a climbing shrub, and in Southern Chile has a wide geographical and altitudinal distribution.

Observed anatomical features:

Transversal Plane: diffuse porous wood. Vessel elements are found usually in radial series 2-4. Rays are notorious.

Longitudinal plane: vessel elements show scalariform perforation plates and scalariform to reticulate pitting. Rays are long and wide.

36. *Drimys winteri* J.R. Forst. & G. Forst., Winteraceae

Drimys is the only native genus of the Winteraceae family, and in Southern Chile comprises two species: *Drimys andina* (Reiche) R. A. Rodr. & Quezada and *Drimys winteri*. For this last taxon there are two varieties (var. *winteri* and var. *chilensis),* but they have never been differentiated in terms of their wood anatomy. Since *D. andina* is a shrub with a clear distribution restricted to high altitudes (over 800 m ASL), based on the distribution of the archaeological sites, the fragments were assigned to species level (but without considering the varieties).

Observed anatomical features:

Transversal Plane: non-porous wood, wood tissue composed of tracheid fibres and parenchyma cells. Growth rings are visible due to the size reduction of tracheid cells.

Longitudinal plane: rays are uniseriate and multiseriate, heterogenous. The multiseriate rays are big and very notorious (around 60-100 cell of height and 4-10 cells of with).

UNKNOWN TYPES

Type A: porous wood, vessel elements found in clusters with no specific pattern. In the longitudinal planes, spiral thickness was observed. Rays are mostly triseriates, but overall small.

This unknown type shares similarities with *Ovidia andina* (Poepp. & Endl.) Meisn., but also with some taxa from the Rhamnaceae, so, at the moment the adscription is uncertain.

Type B: diffuse porous wood, vessel are abundant and small, angular outline shape. Rays are heterogenous, they are uniseriate, biseriate and triseriate.

This unknown type shares similarities with *Aextoxicon punctatum* and *Laurelia/Laureliopsis*, but unlike both of them, scalariform perforation plates were absent or not observed, so the taxonomical assignation is uncertain.

Type C: Diffuse porous wood, vessel elements big and found in clusters of two or more cells. Wide rays and very distinctive in transversal plane. In the longitudinal plane, only simple perforation plates were observed. Vessel pitting extremely small. Presence of multiseriate rays, abundant.

This unknown type shares similarities with *Fuchsia magellanica*, but at the same time, certain features do not fit the description of the taxon (e.g., pitting of vase elements).

Type D: Diffuse porous wood, most pores are small and arranged in radials series (2-4 cells). Growth rings are visible due the flattening of woody fibres. Simple perforation plates, ray-vessel pitting are big and visible. Spiral thickening present. Rays are uniseriate, biseriate and triseriate.

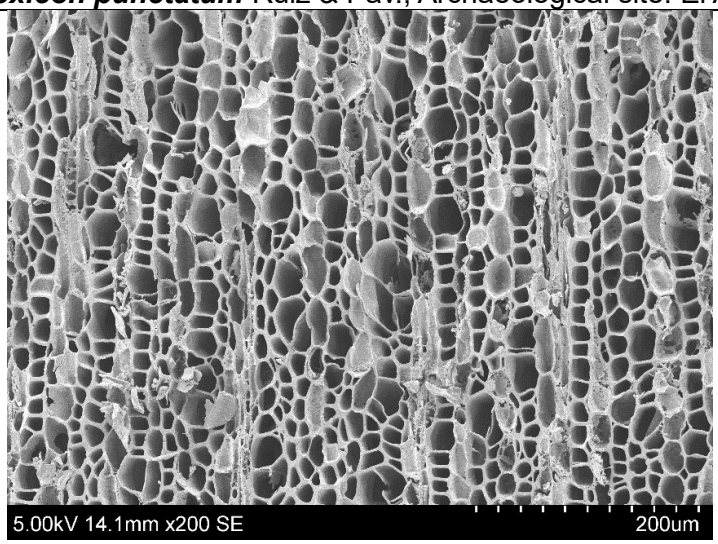
This unknown type fits the available descriptions of the *Colliguaja* genus, family Euphorbiaceae, but since the descriptions do not cover all species and genera in the family, the assignation to the genera or family is uncertain.

Type E: diffuse porous wood, pores small, abundant and showing polygonal shape. In the longitudinal plane, scalariform perforation plates were observed (few bars, around 10), and spiral thickness is abundant. Rays are uni to triseriate, short and abundant.

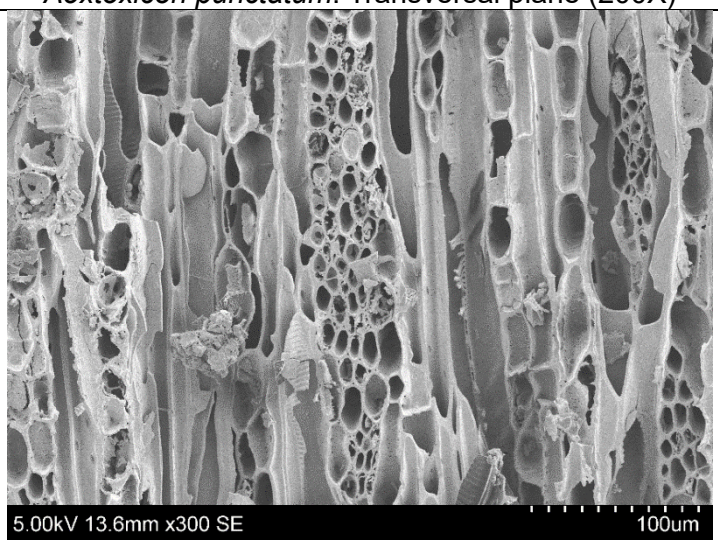
Because not many species have scalariform plates, this unknown type could correspond to one undescribed Myrtaceae species, but also and undescribed Azara (Salicaceae), or even to *Gomortega keule* (Molina) Baill. So, at the moment the ascription is uncertain.

SEM images of Identified taxa (number according to previous descriptions)

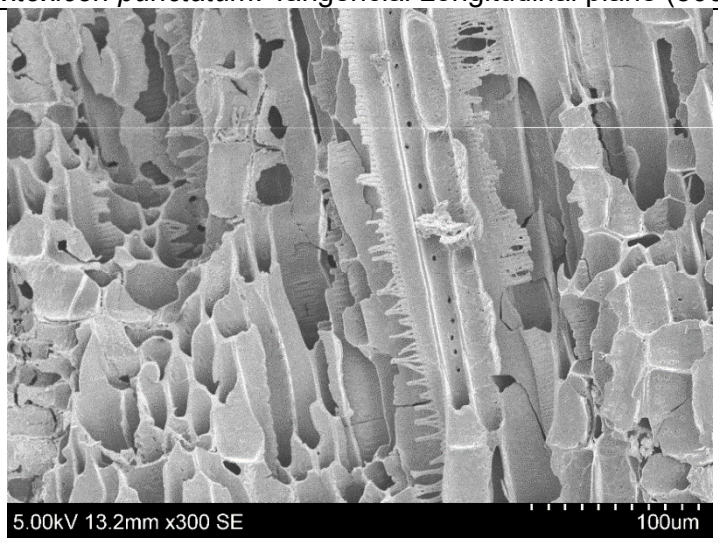
1. Aextoxicon punctatum Ruiz & Pav., Archaeological site: El Arenal-1



Aextoxicon punctatum: Transversal plane (200X)

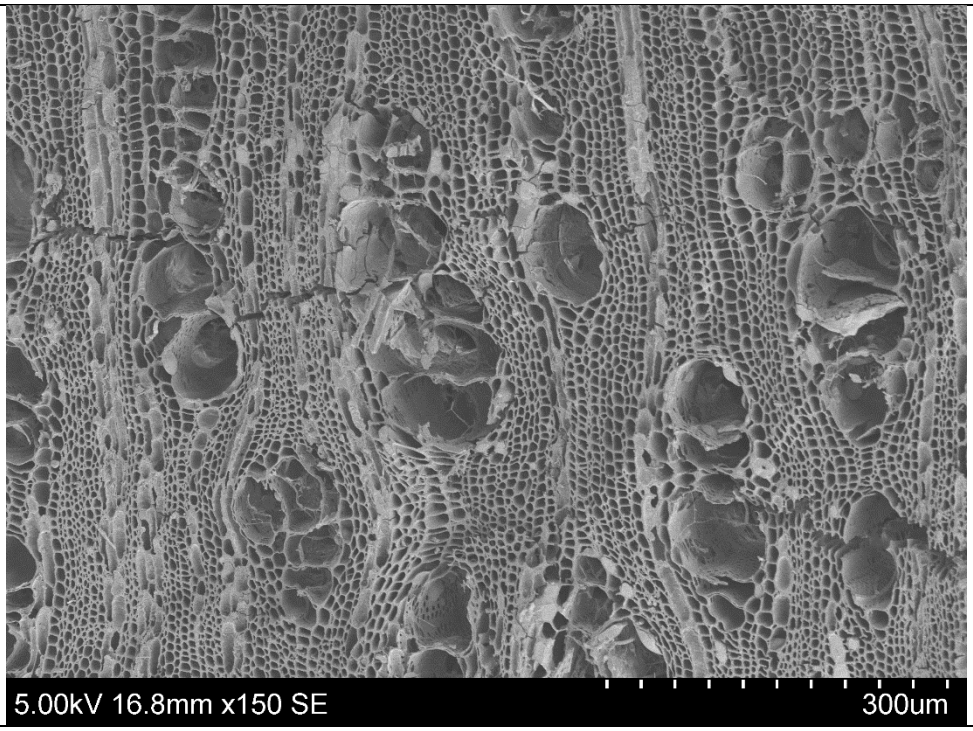


Aextoxicon punctatum: Tangencial Longitudinal plane (300X)

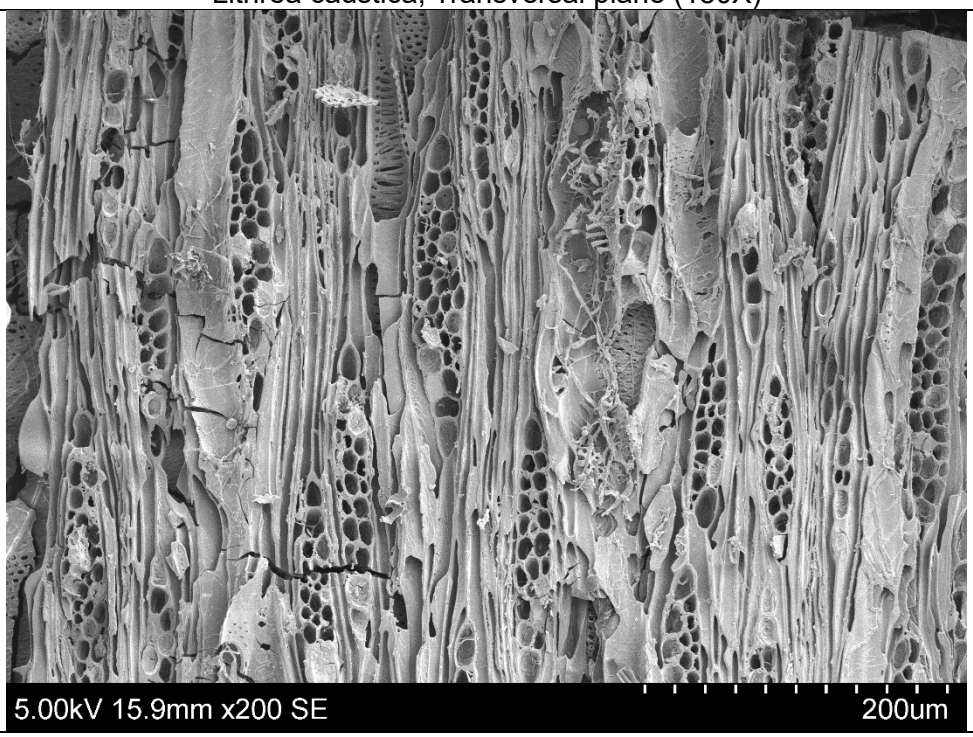


Aextoxicon punctatum: Radial I Longitudinal plane (300X)

3. *Lithrea caustica* (Molina) Hook. & Arn., Anacardiaceae, Archaeological site: Cueva de los Catalanes U1

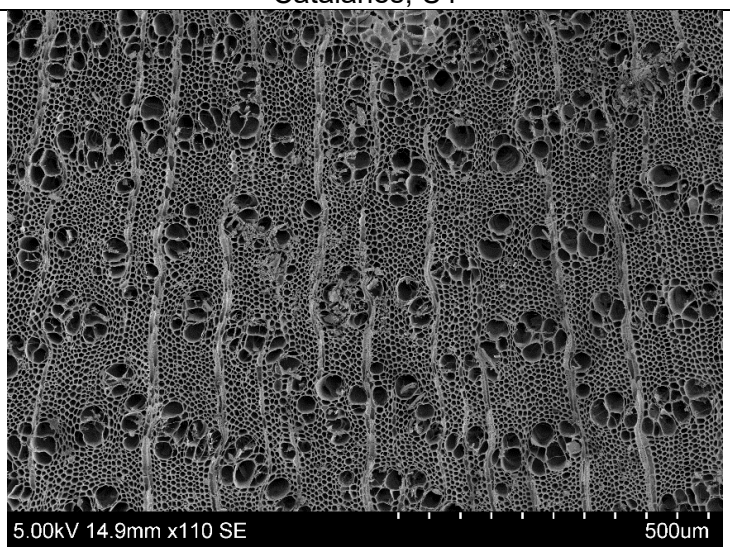


Lithrea caustica, Transversal plane (150X)

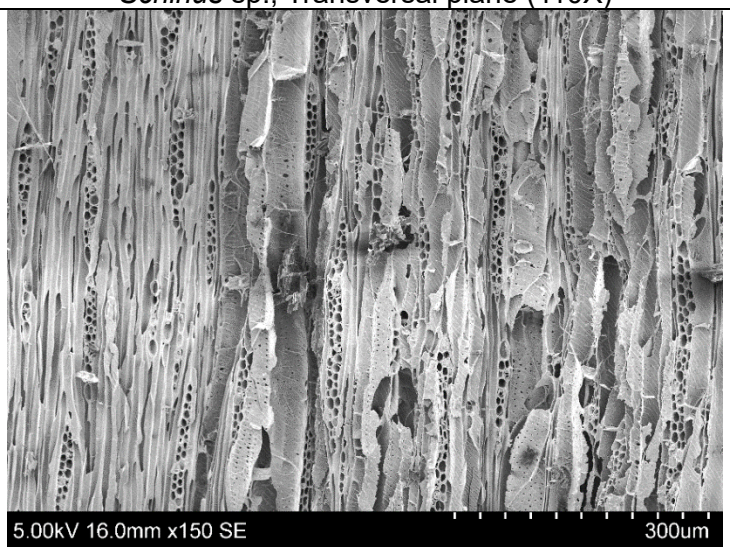


Lithrea caustica, Tangential longitudinal plane (200X)

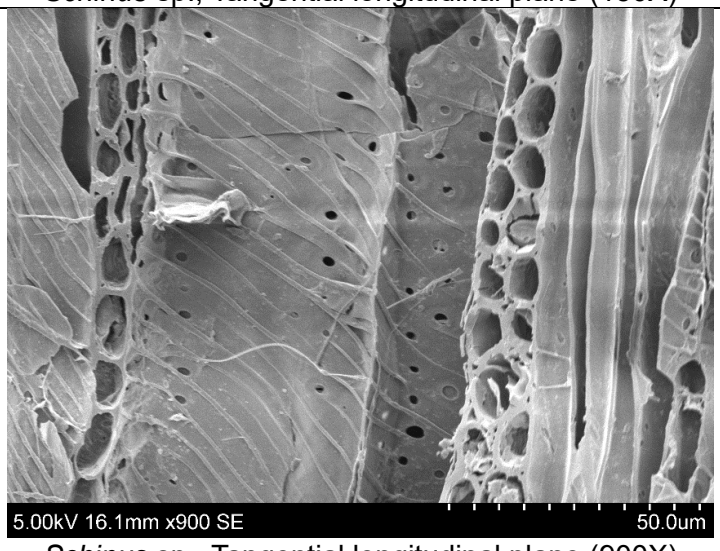
4. *Schinus* sp., Anacardiaceae, Archaeological site: Cueva de los Catalanes, U1



Schinus sp., Transversal plane (110X)

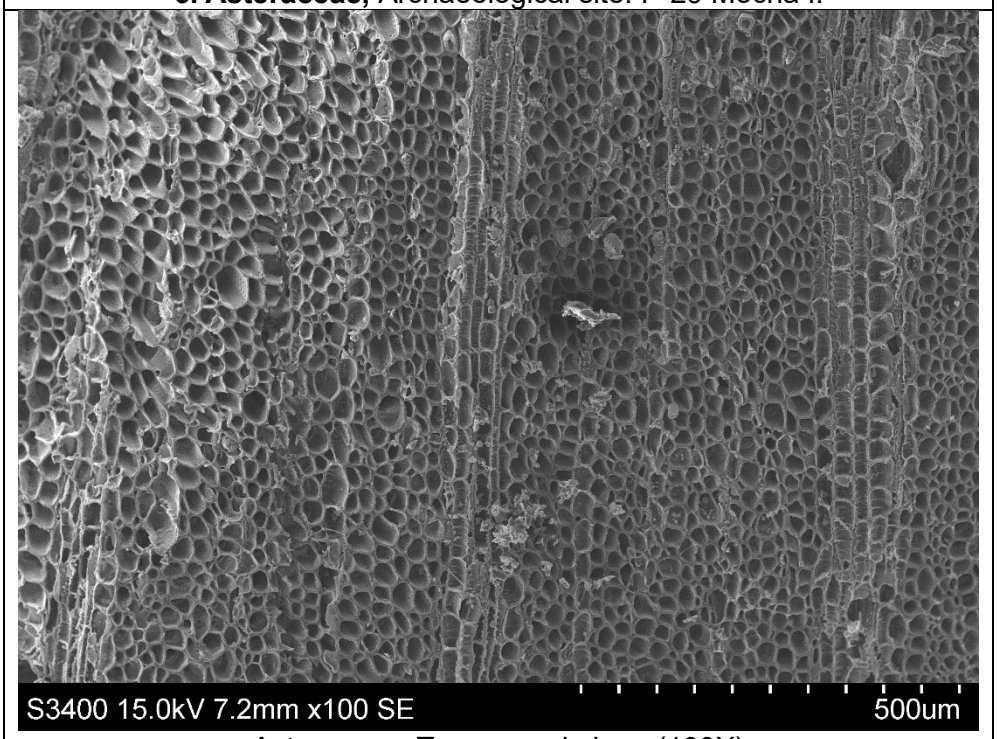


Schinus sp., Tangential longitudinal plane (150X)

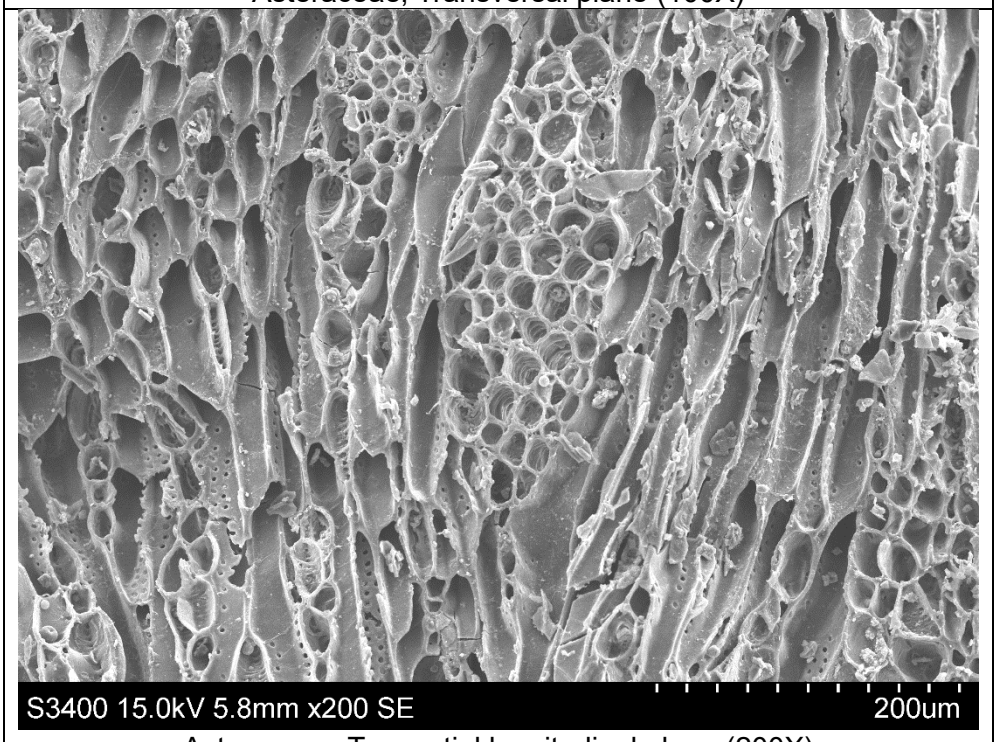


Schinus sp., Tangential longitudinal plane (900X)

6. Asteraceae, Archaeological site: P-29 Mocha I.

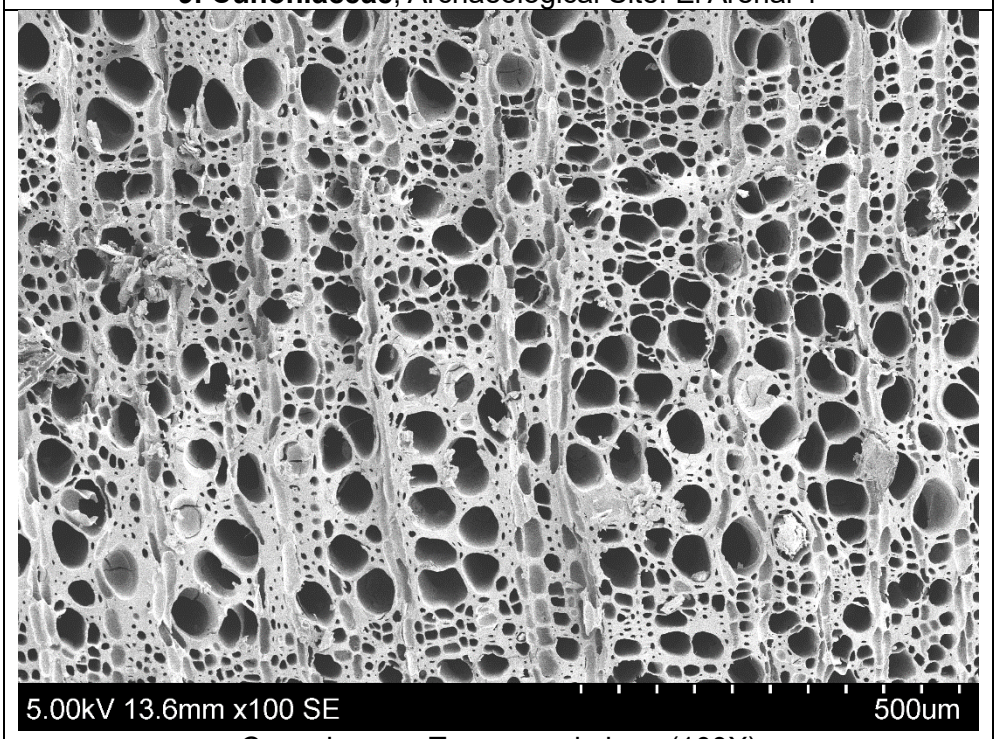


Asteraceae, Transversal plane (100X)

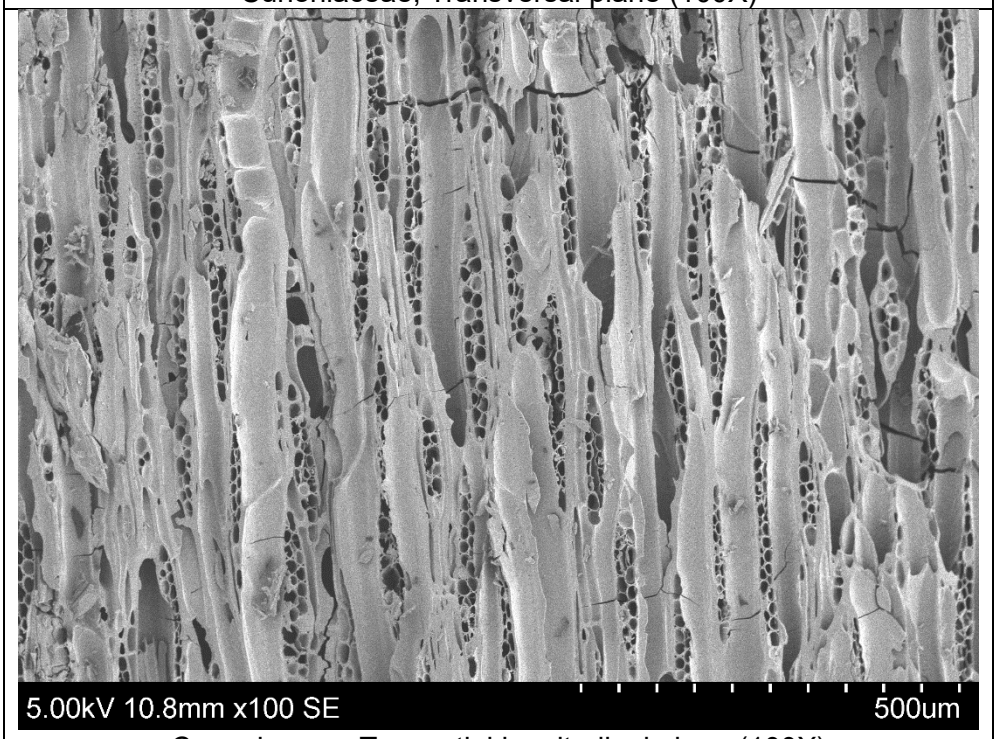


Asteraceae, Tangential longitudinal plane (200X)

9. Cunoniaceae, Archaeological Site: El Arenal-1

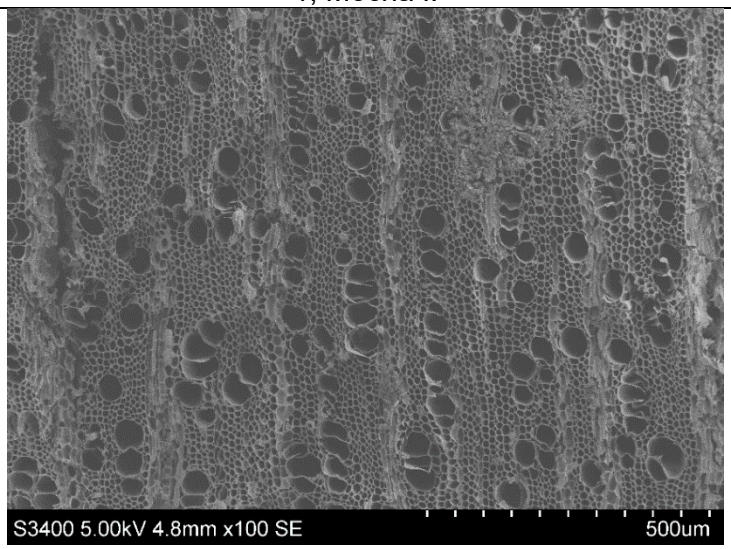


Cunoniaceae, Transversal plane (100X)

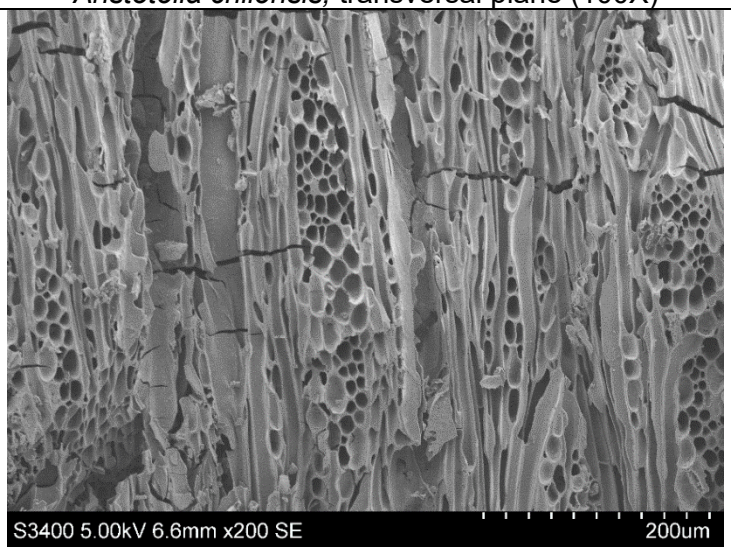


Cunoniaceae, Tangential longitudinal plane (100X)

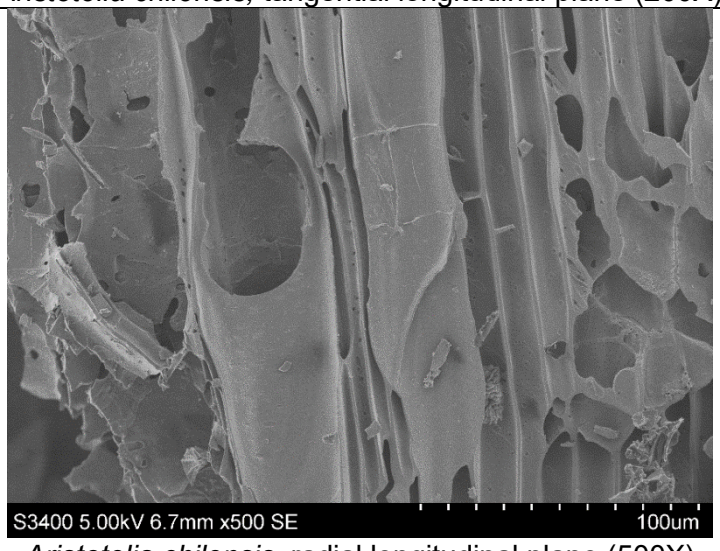
11. *Aristotelia chilensis* (Molina) Stuntz, Eleocarpacae, Archaeological site: P5-1, Mocha I.



Aristotelia chilensis, transversal plane (100X)

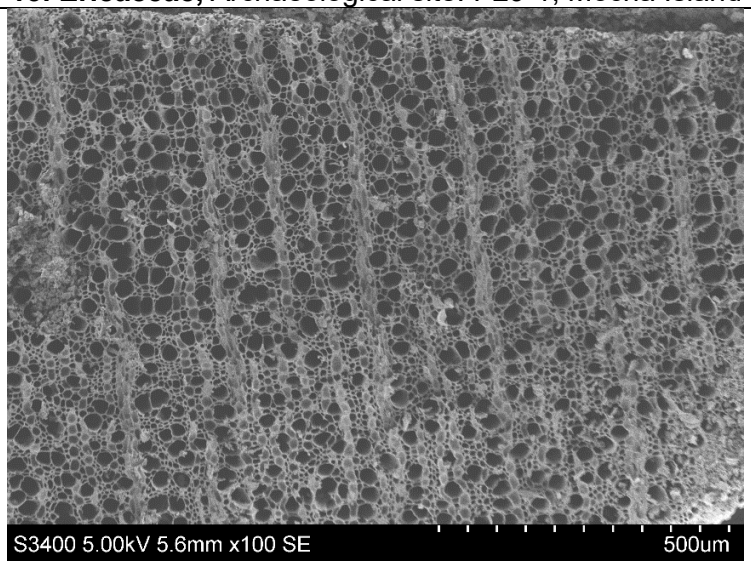


Aristotelia chilensis, tangential longitudinal plane (200X)

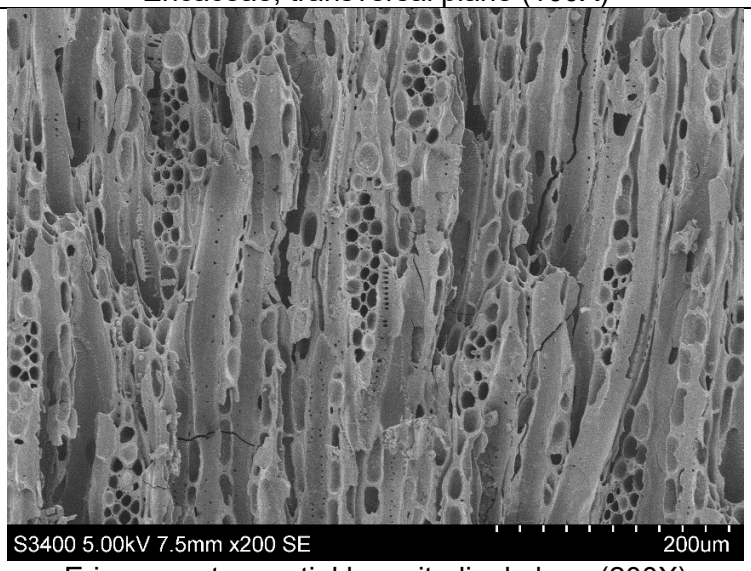


Aristotelia chilensis, radial longitudinal plane (500X)

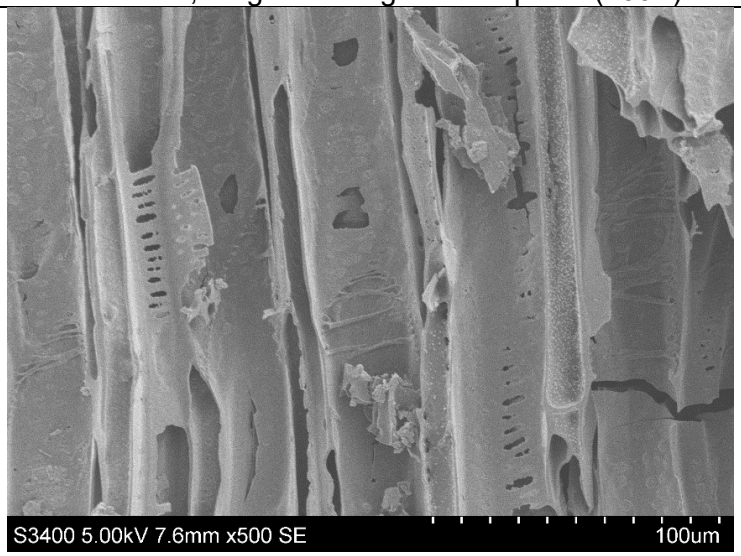
13. Ericaceae, Archaeological site: P29-1, Mocha Island



Ericaceae, transversal plane (100X)

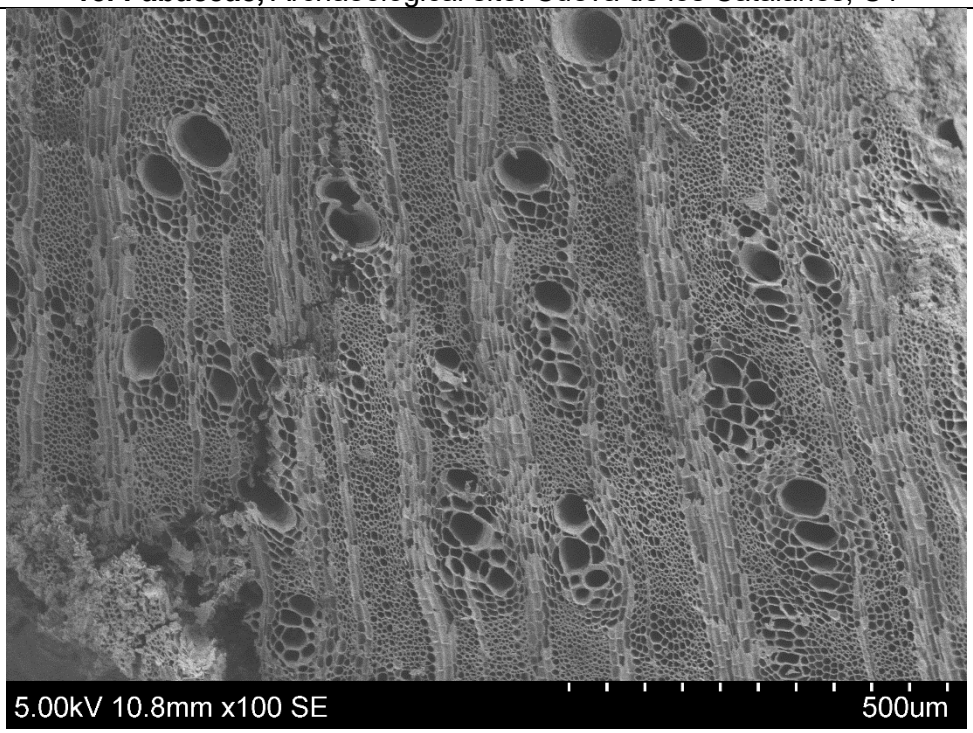


Ericaceae, tangential longuitudinal plane (200X)

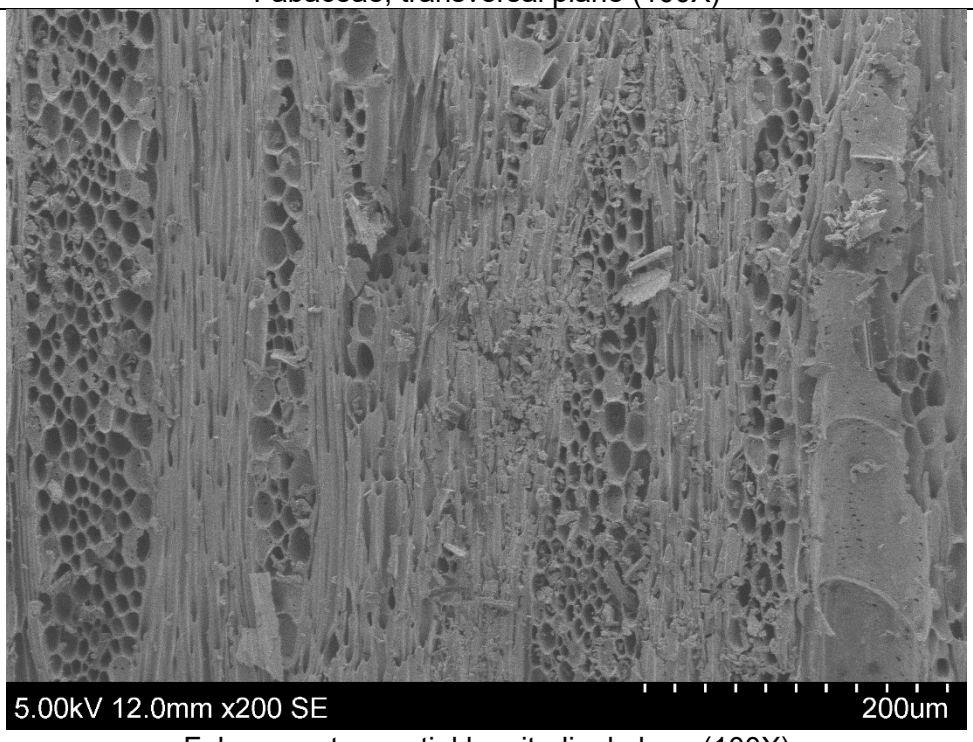


Ericaceae, radial longuitudinal plane (500X)

15. Fabaceae, Archaeological site: Cueva de los Catalanes, U1

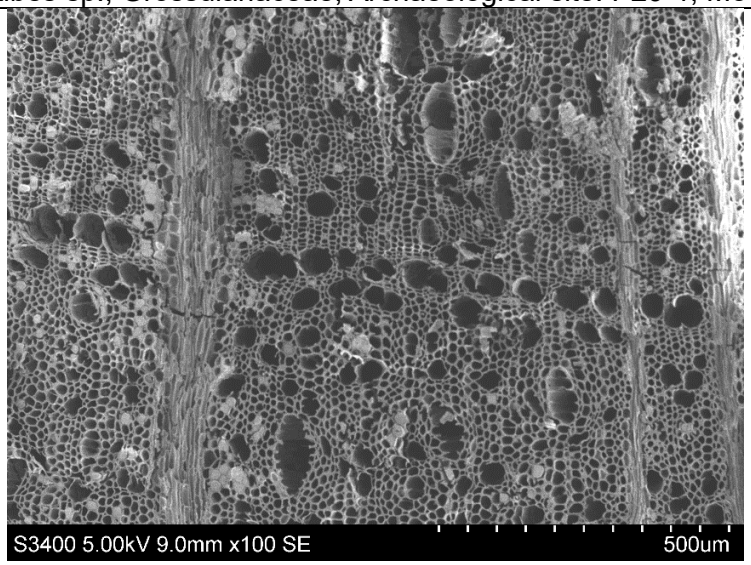


Fabaceae, transversal plane (100X)

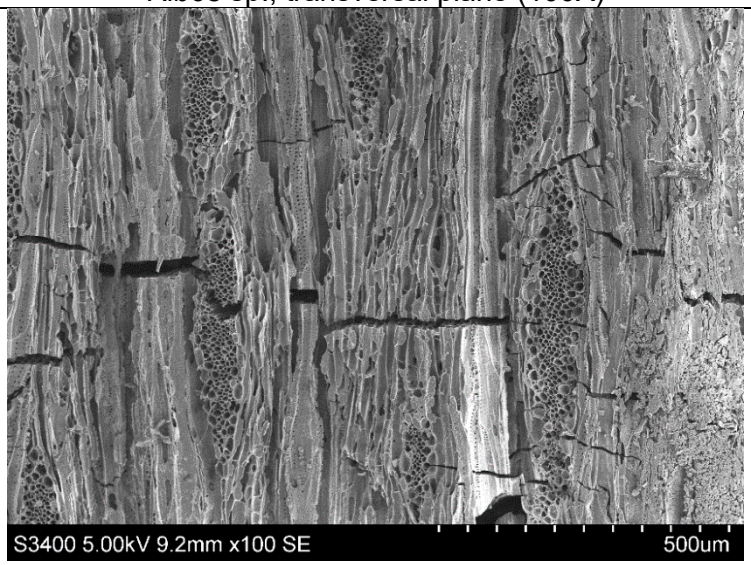


Fabaceae, tangential longitudinal plane (100X)

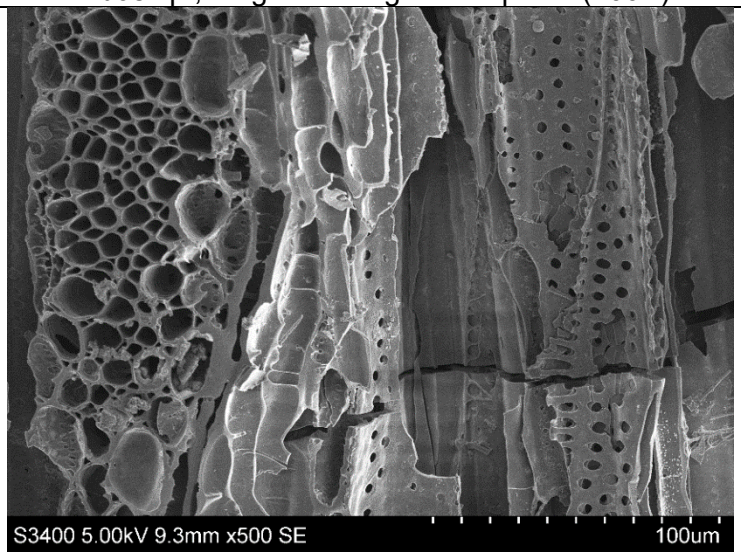
16. Ribes sp., Grossulariaceae, Archaeological site: P29-1, Mocha I.



Ribes sp., transversal plane (100X)

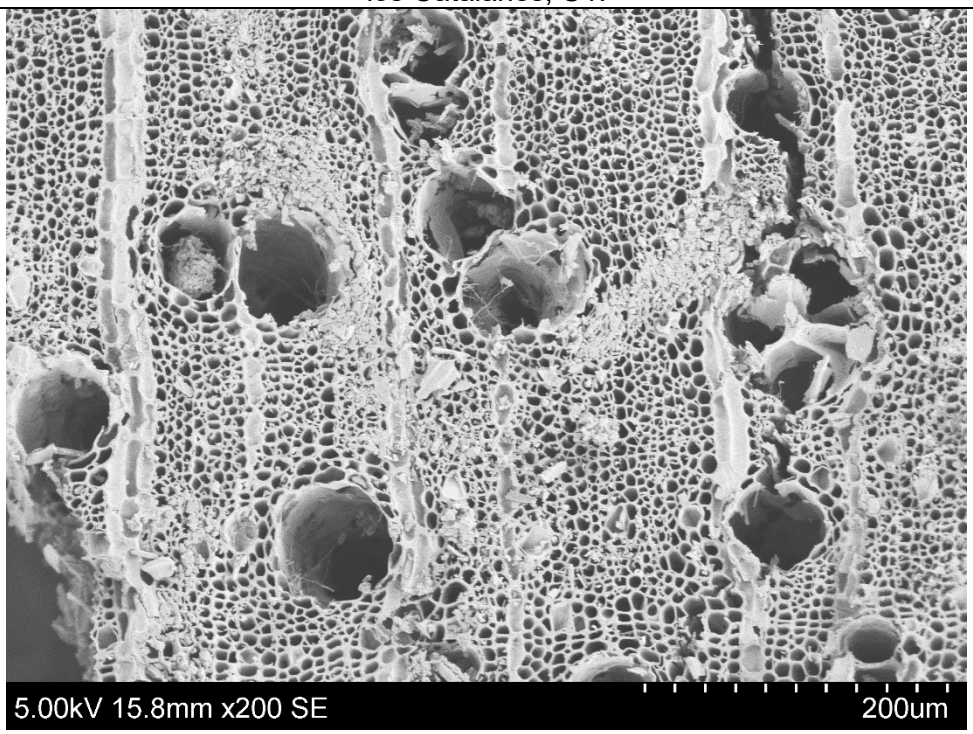


Ribes sp., tangential longitudinal plane (100X)



Ribes sp., tangential longitudinal plane (500X)

17. *Cryptocarya alba* (Molina) Looser., Lauraceae. Archaeological site: Cueva de los Catalanes, U1.

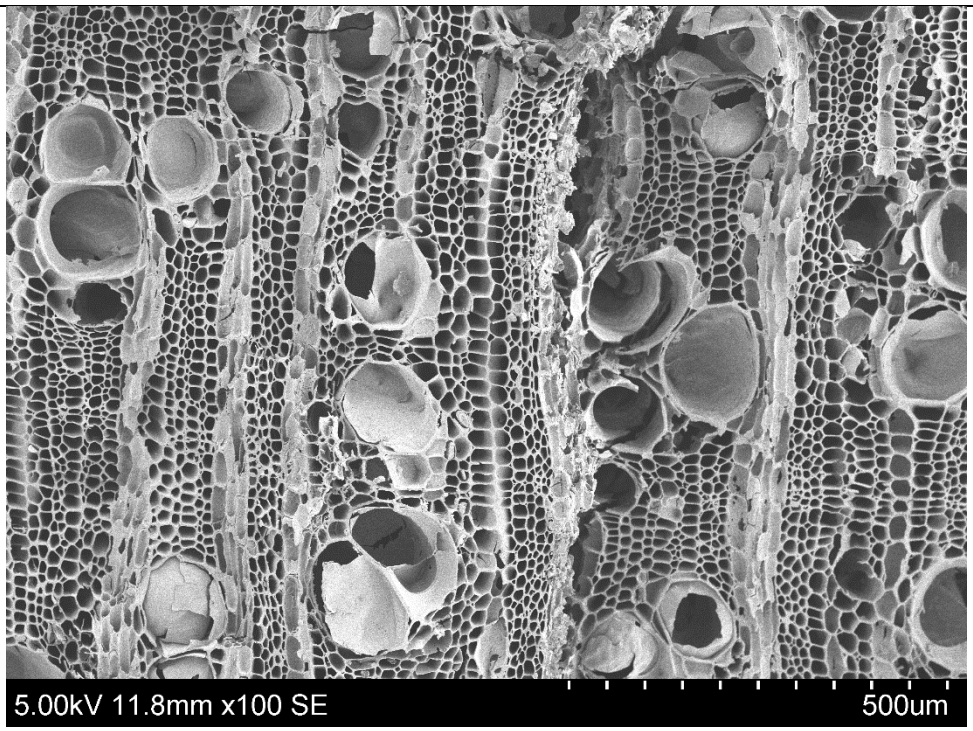


Cryptocarya alba, transversal plane (200X)

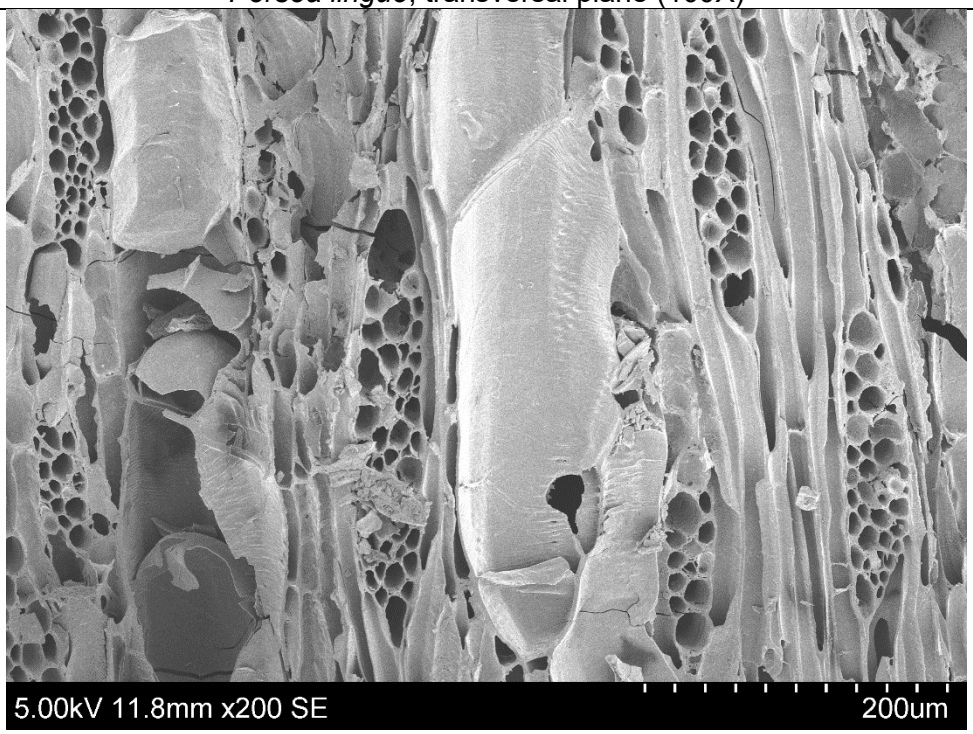


Cryptocarya alba, tangencial longitudinal plane (200X)

18. *Persea lingue* (Ruiz & Pav.) Nees., Lauraceae, Archaeological site: El Arenal-1.

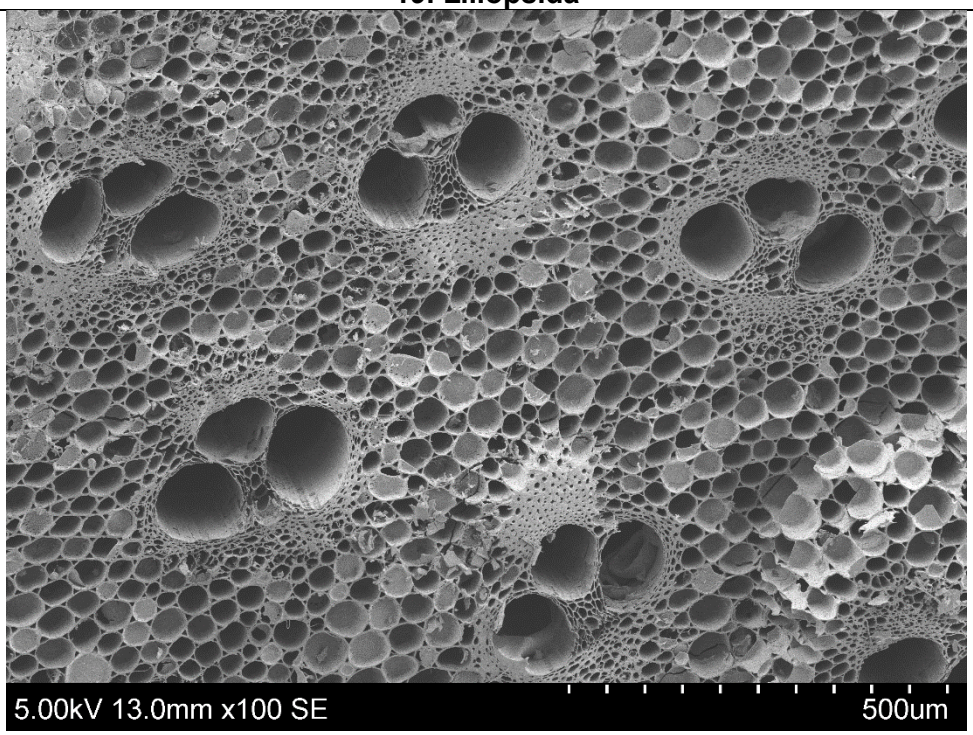


Persea lingue, transversal plane (100X)

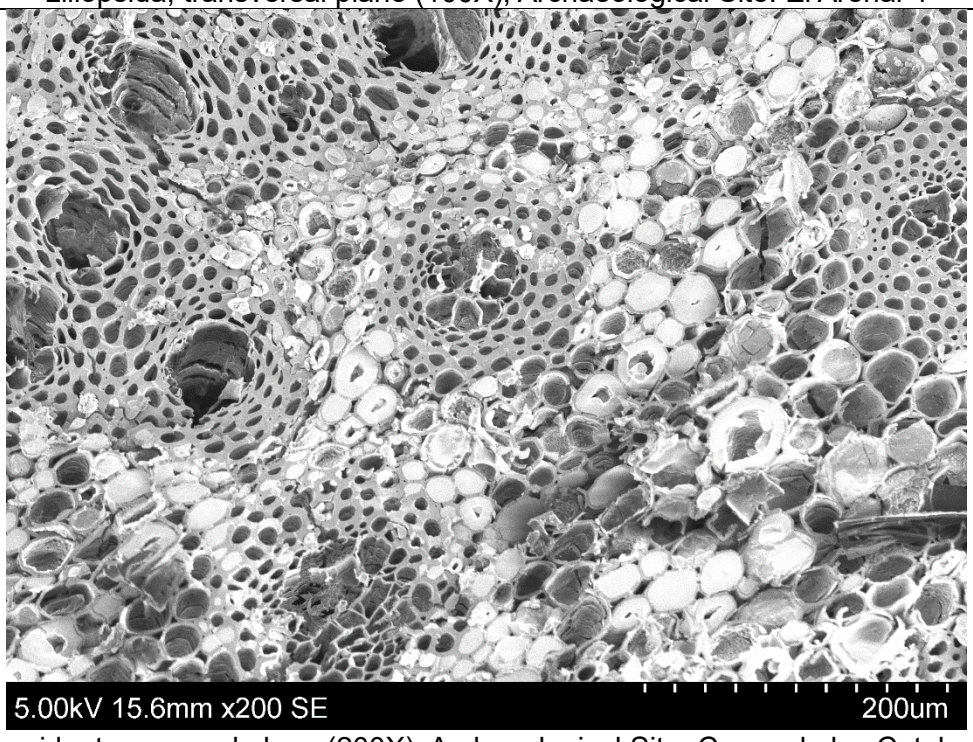


Persea lingue, tangencial longitudinal plane (100X)

19. Liliopsida

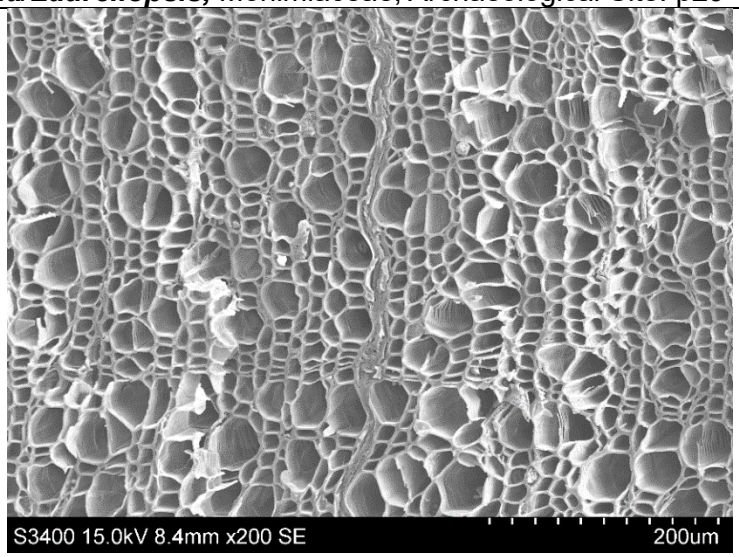


Liliopsida, transversal plane (100X), Archaeological Site: El Arenal-1

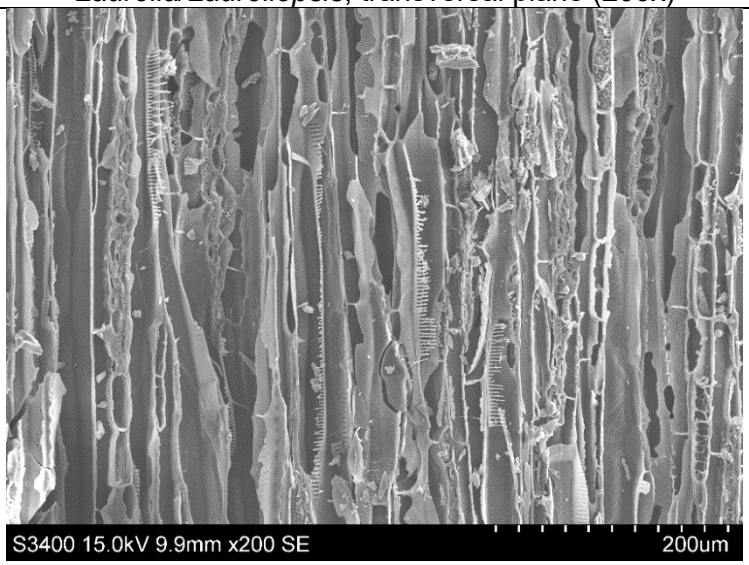


Liliopsida, transversal plane (200X), Archaeological Site: Cueva de los Catalanes, U1

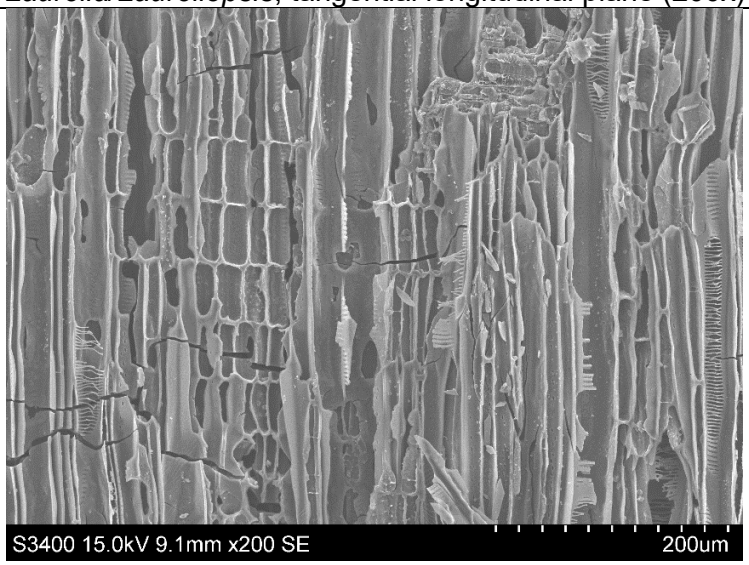
20*. Laurelia/Laureliopsis,* Monimiaceae, Archaeological Site: p29-1, Mocha I.



Laurelia/Laureliopsis, transversal plane (200x)

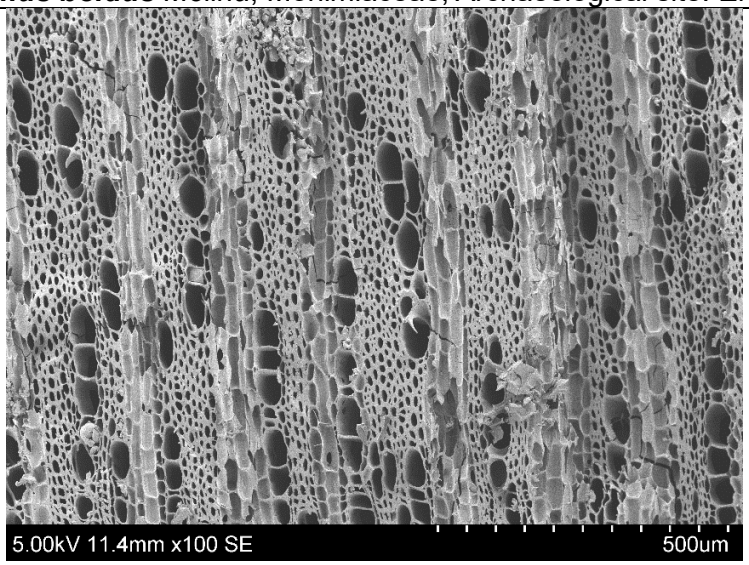


Laurelia/Laureliopsis, tangential longitudinal plane (200x)

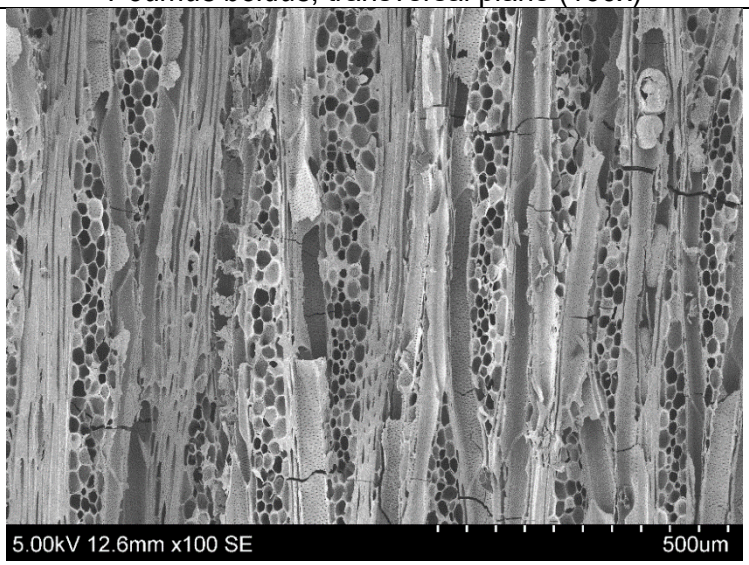


Laurelia/Laureliopsis, radial longitudinal plane (200x)

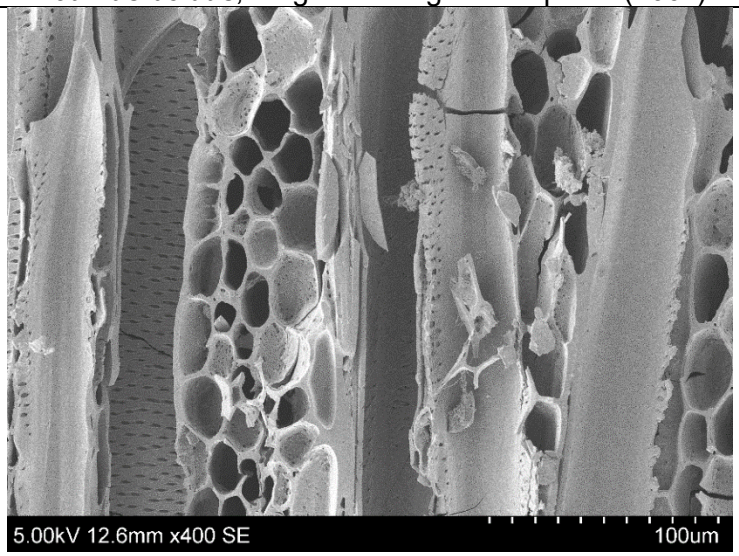
21. *Peumus boldus* *Molina*, Monimiaceae, Archaeological site: El Arenal-1



Peumus boldus, transversal plane (100x)

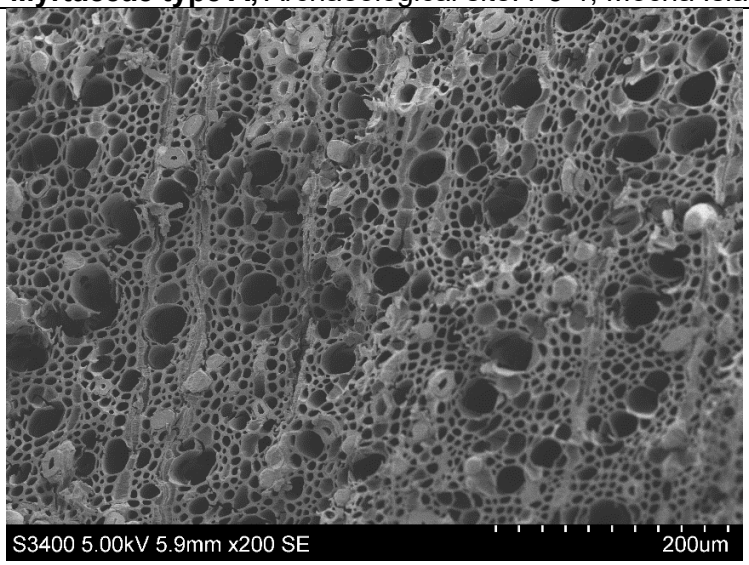


Peumus boldus, tangential longitudinal plane (100x)

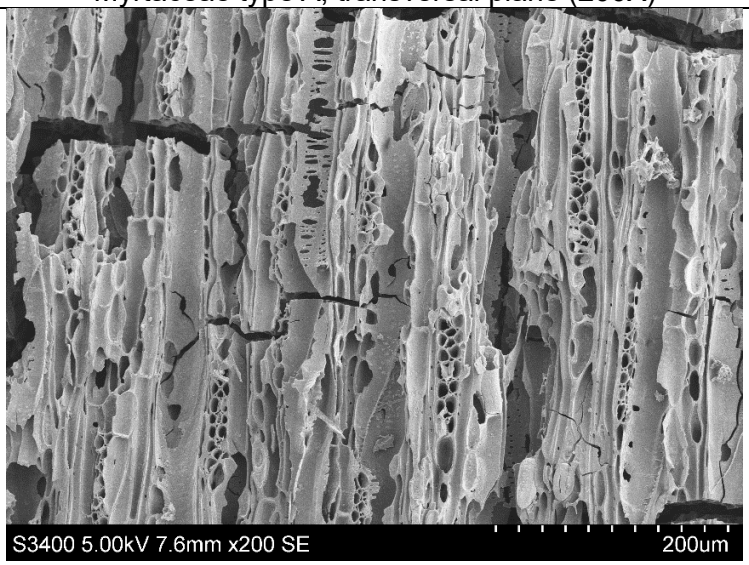


Peumus boldus, tangential longitudinal plane (400x)

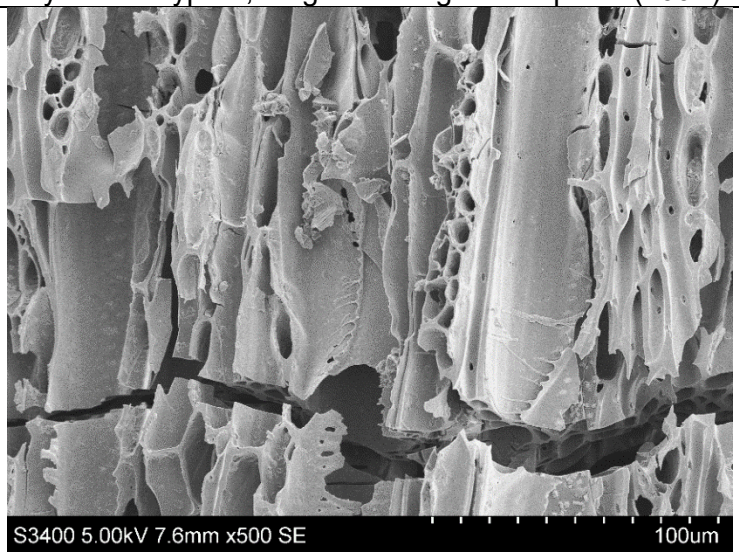
22. Myrtaceae type A, Archaeological site: P5-1, Mocha Island.



Myrtaceae type A, transversal plane (200X)

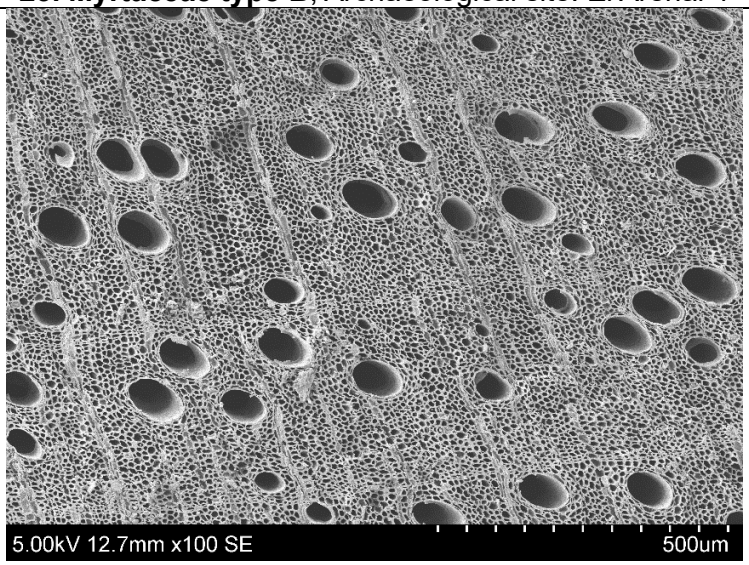


Myrtaceae type A, tangential longitudinal plane (200X)

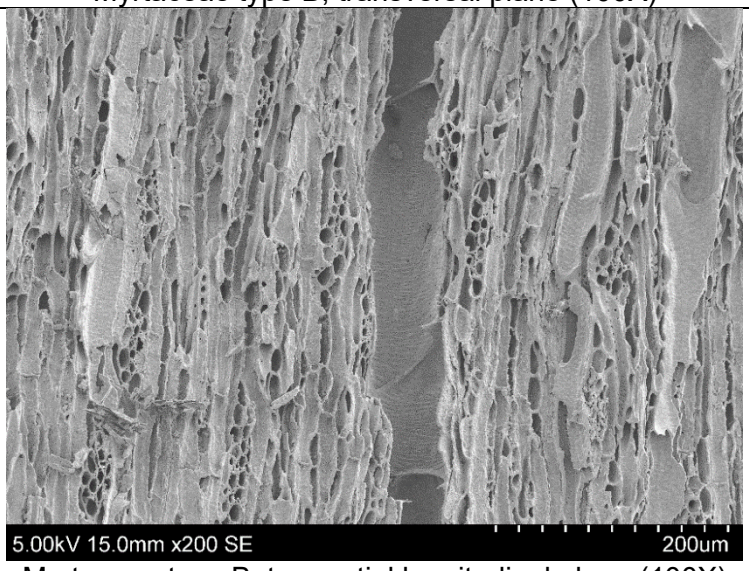


Myrtaceae type A, tangential longitudinal plane (500X)

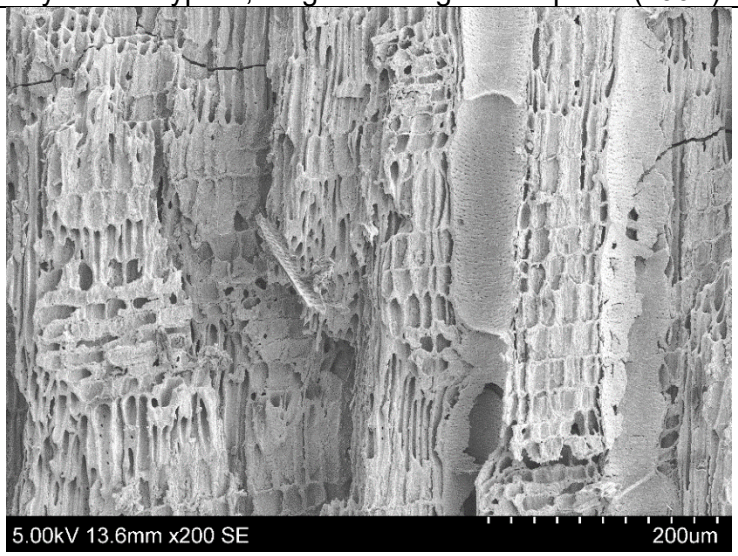
23. Myrtaceae type B, Archaeological site: El Arenal-1



Myrtaceae type B, transversal plane (100X)

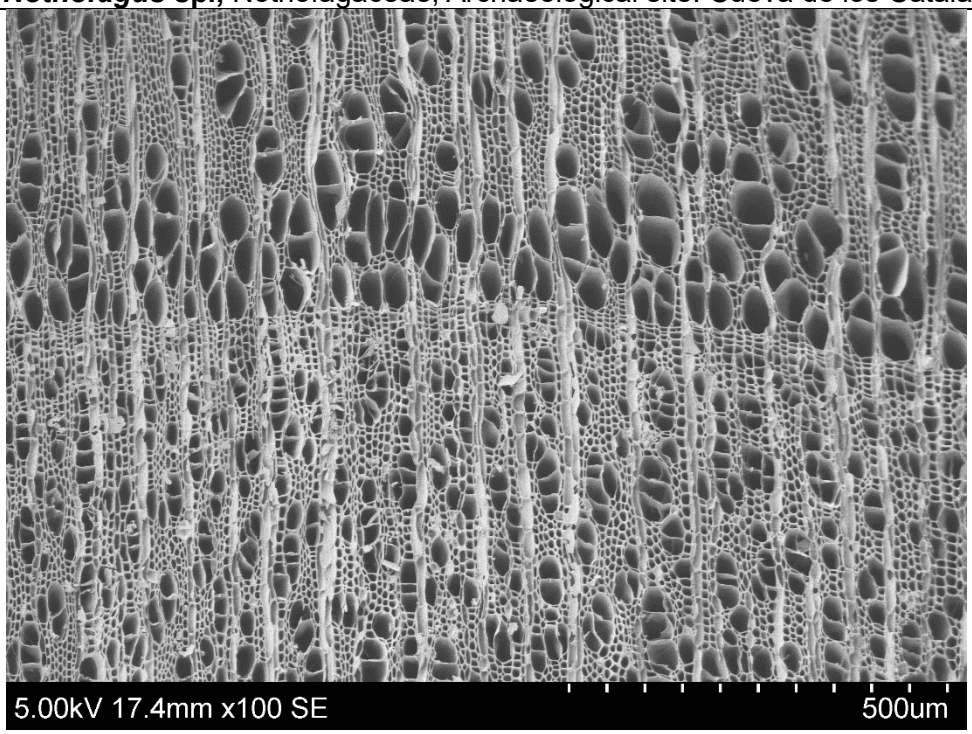


Myrtaceae type B, tangential longitudinal plane (100X)

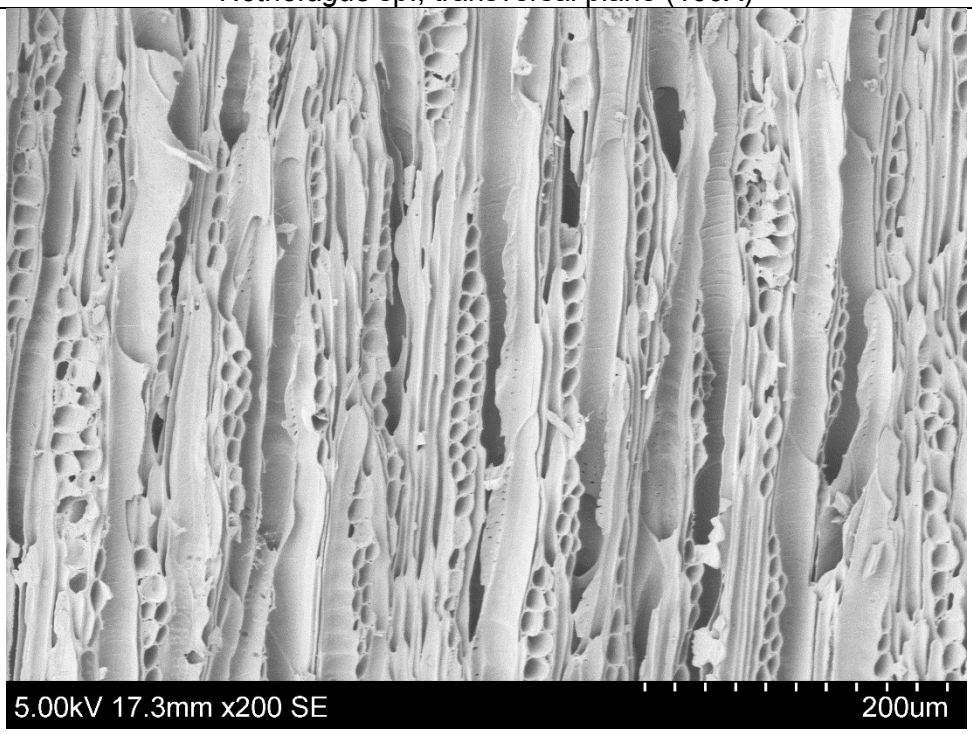


Myrtaceae type B, radial longitudinal plane (100X)

24. *Nothofagus* sp., Nothofagaceae, Archaeological site: Cueva de los Catalanes

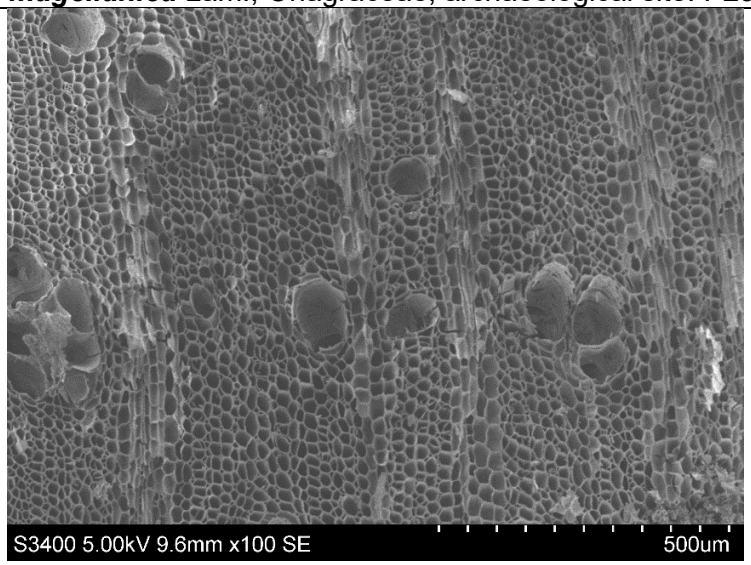


Nothofagus sp., transversal plane (100X)

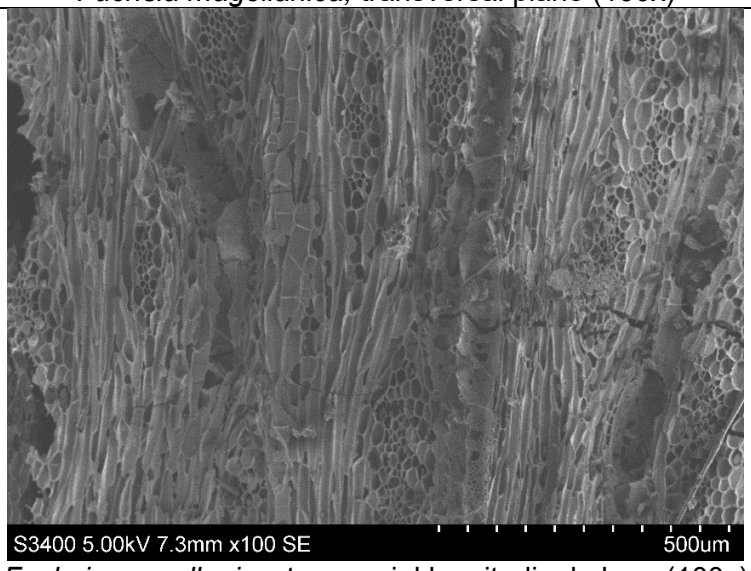


Nothofagus sp., tangential longitudinal plane (100X)

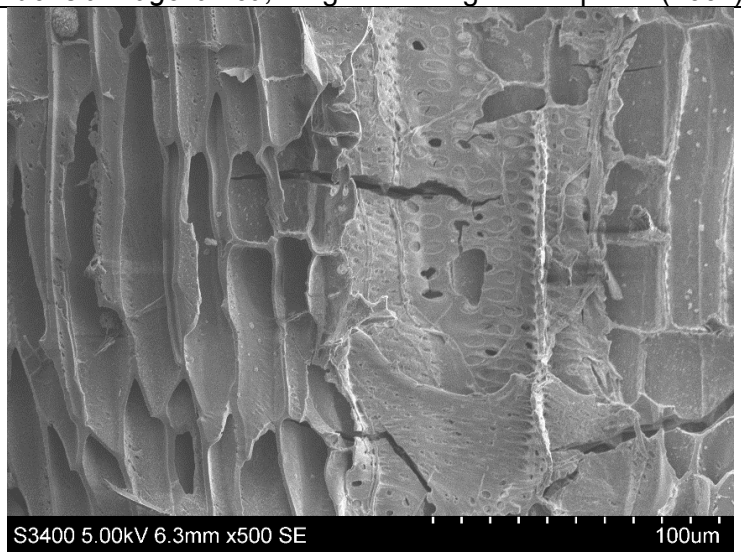
25. Fuchsia magellanica Lam., Onagraceae, archaeological site: P29-1, Mocha I.



Fuchsia magellanica, transversal plane (100x)

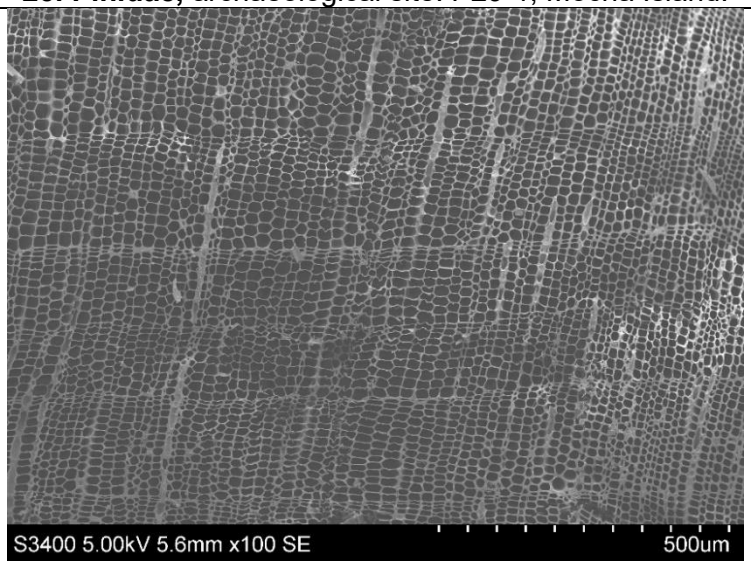


Fuchsia magellanica, tangencial longitudinal plane (100x)

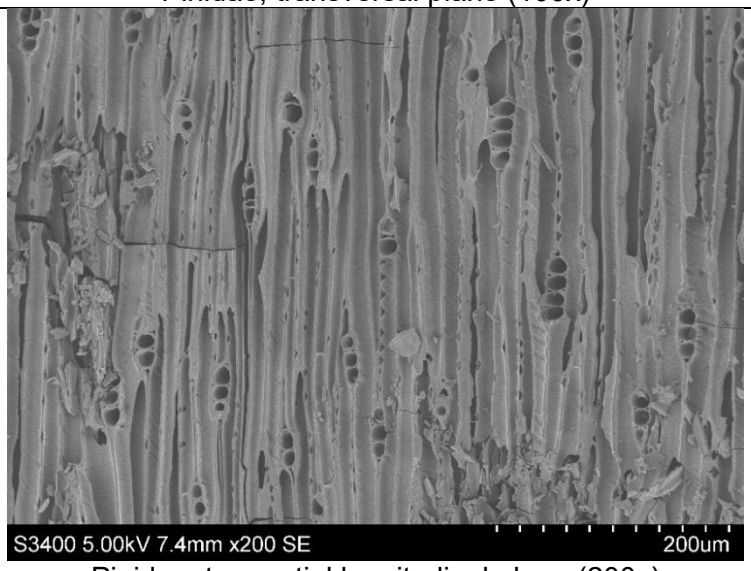


Fuchsia magellanica, radial longitudinal plane (500x)

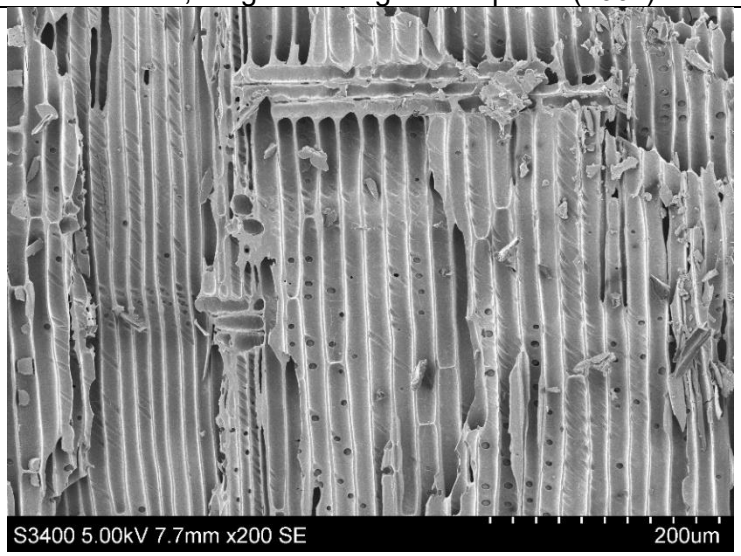
25. Pinidae, archaeological site: P29-1, Mocha Island.



Pinidae, transversal plane (100x)

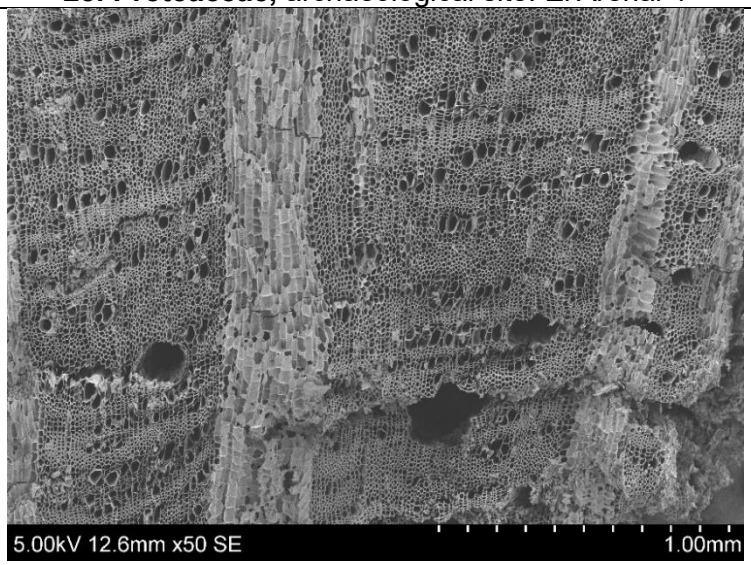


Pinidae, tangential longitudinal plane (200x)

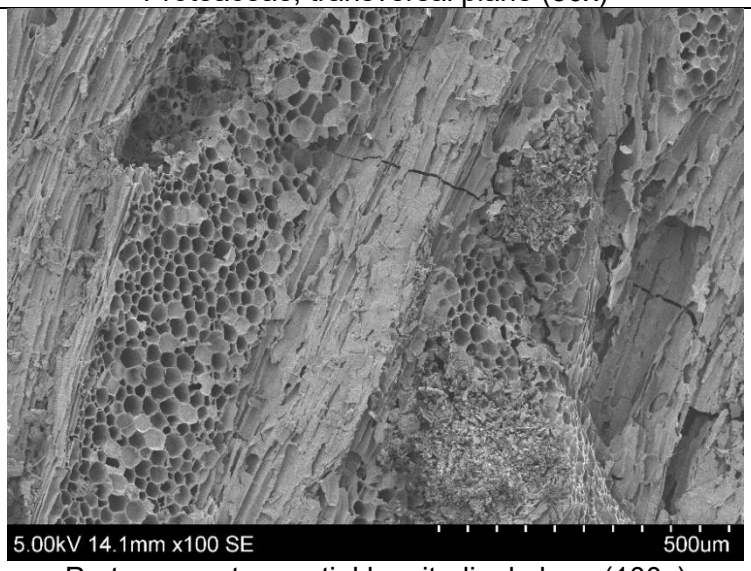


Pinidae, radial longitudinal plane (200x)

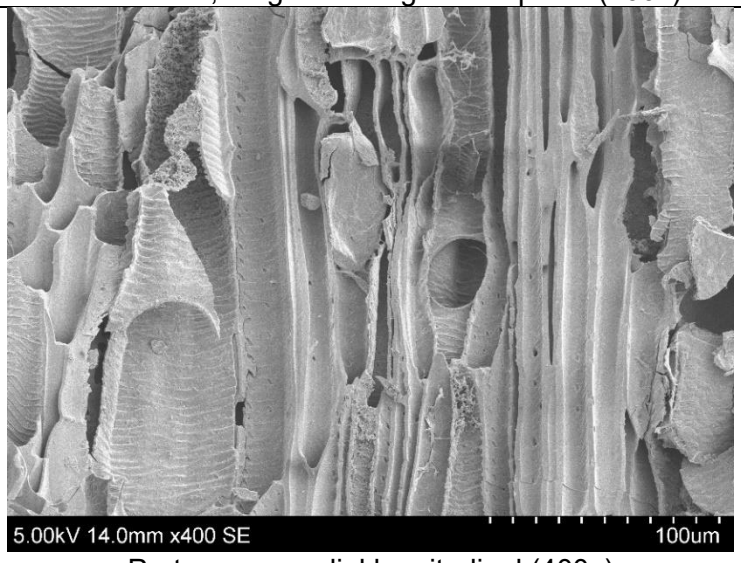
28. Proteaceae, archaeological site: El Arenal-1



Proteaceae, transversal plane (50x)

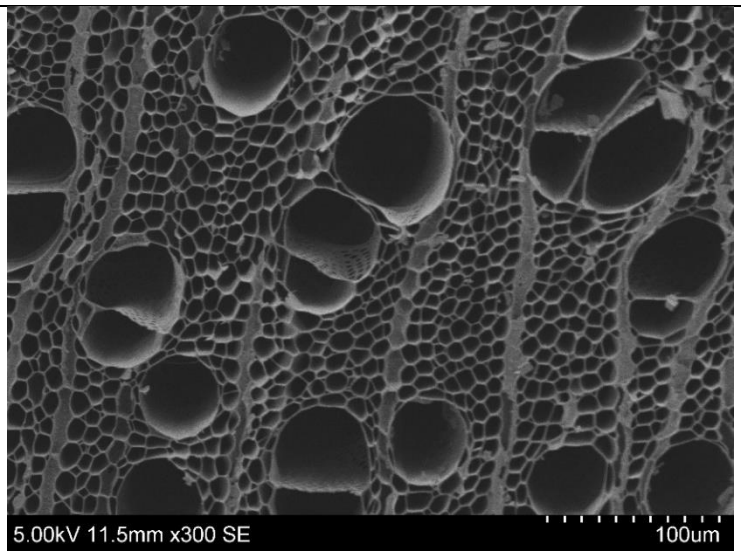


Proteaceae, tangential longitudinal plane (100x)

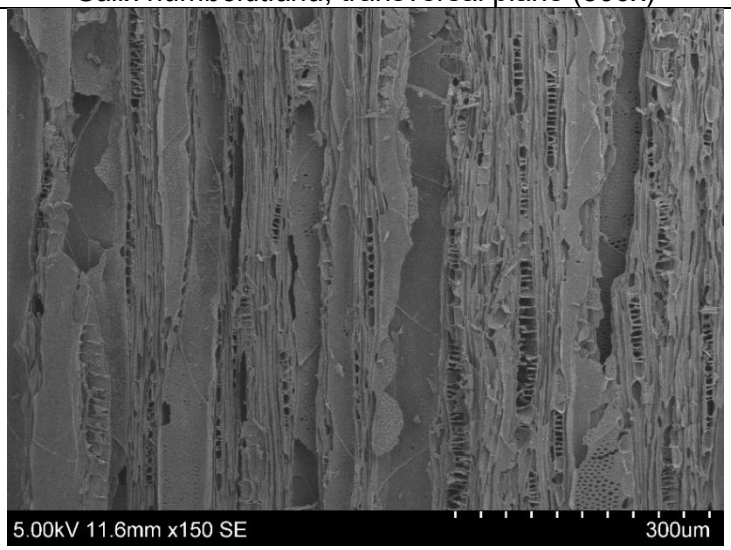


Proteaceae, radial longitudinal (400x)

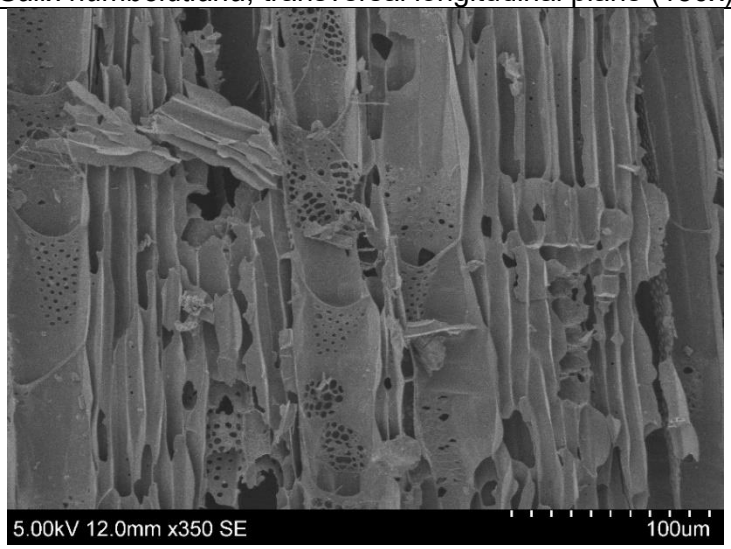
32. *Salix humboldtiana* Willd**,** Salicaceae archaeological site: U1 Cueva de los Catalanes



Salix humboldtiana, transversal plane (300x)

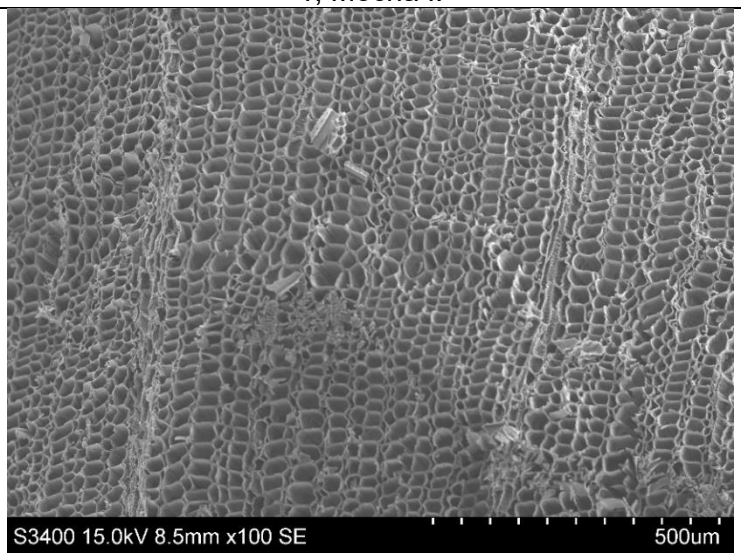


Salix humboldtiana, transversal longitudinal plane (150x)

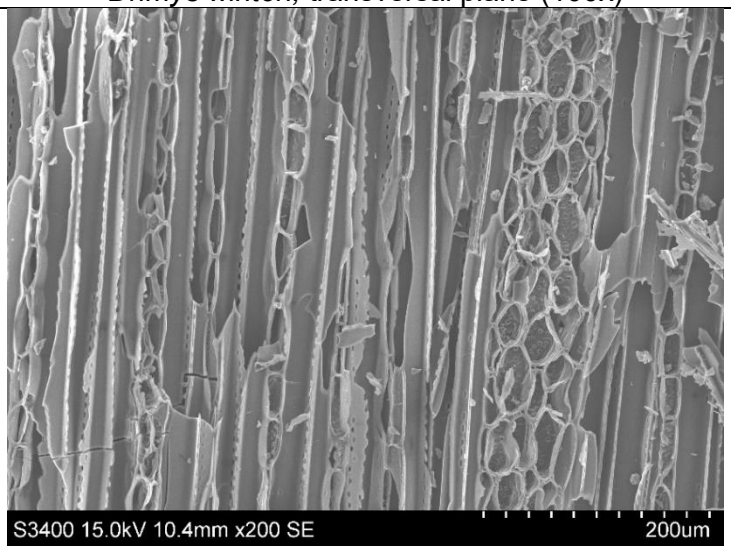


Salix humboldtiana, radial longitudinal plane (350x)

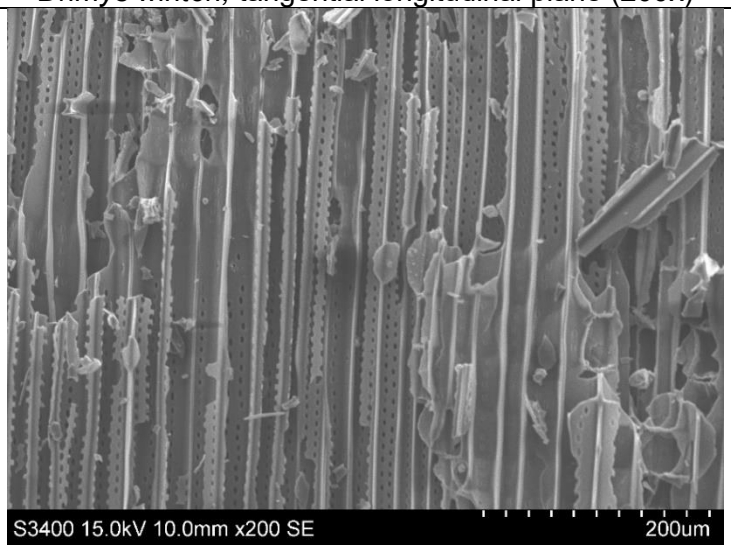
36. Drimys winteri J.R. Forst. & G. Forst., Winteraceae, Archaeological site: P29-1, Mocha I.



Drimys winteri, transversal plane (100x)

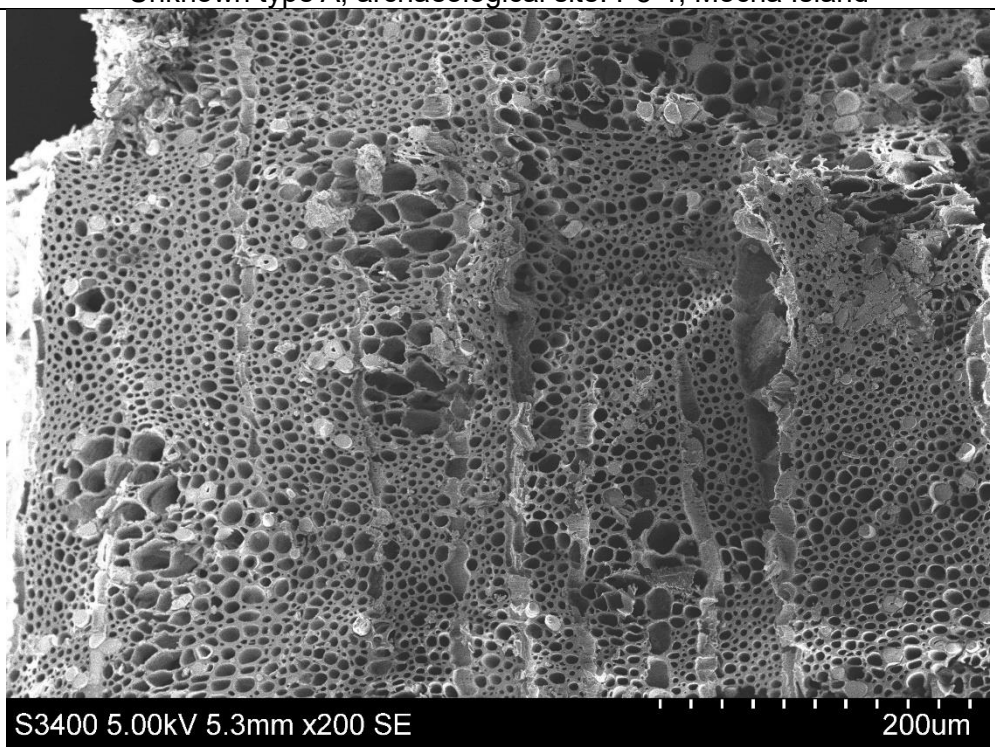


Drimys winteri, tangential longitudinal plane (200x)

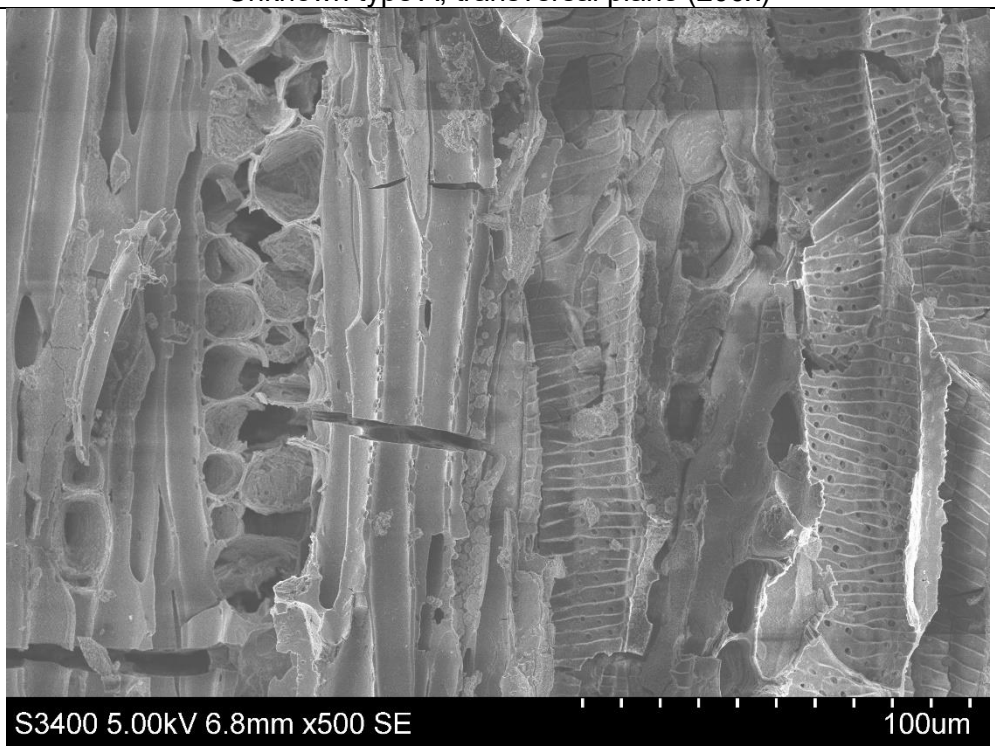


Drimys winteri, radial longitudinal plane (100x)

Unknown type A, archaeological site: P5-1, Mocha Island



Unknown type A, transversal plane (200x)



Unknown type A, tangential longitudinal plane (500x)