Fundamental Issues in Archaeology

Oreto García-Puchol
Domingo C. Salazar-García *Editors*

Times of Neolithic Transition along the Western Mediterranean

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About the Editors

Oreto García-Puchol received her Ph.D. in History from Universitat de València in 2002. From 2010 to 2015 she was a Ramon y Cajal researcher at the Department of Prehistory, Archaeology and Ancient History (Universitat de València), where currently she is a Ph.D. researcher integrated in the PREMEDOC Research Group. She specializes in socioecological dynamics during the recent Prehistory in the Western Mediterranean. Her research interests include the Mesolithic, Neolithic transition, cultural transmission, lithic technology, the emergence of social hierarchies, Mesolithic and Neolithic funerary practices and 3D Archaeology. She has directed archaeological fieldworks in the Mediterranean basin of Iberia, including at Falguera Rock Shelter, Pastora Cave and at Cocina Cave. Currently she heads the EVOLPAST Research Project funded by the Government of Spain.

Domingo C. Salazar-García (born Valencia, 1981; Ph.D. Leipzig-Valencia, 2012) is a biomolecular archaeologist whose research focuses on the reconstruction of lifestyles from prehistoric and early historic time periods. Especially interested in the transition to farming, he is working mainly on projects in the Mediterranean, South America and Southern Africa. He tracks human diet, health and migration through biogeochemical (isotope and proteomic analysis) and microscopic techniques on a range of human tissues (bone, teeth, hair, dental calculus). His research career has been strongly international, at institutions like the University of Valencia, the Max-Planck Institute for Evolutionary Anthropology, the University of Cape Town, the Max-Planck Institute for the Science of Human History and the University of the Basque Country.

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Chapter 1
Current Thoughts on the Neolithisation Process of the Western Mediterranean

Domingo C. Salazar-García and Oreto García-Puchol

The analysis of the Neolithisation process constitutes a recurrent theme in the scientific literature given the fundamental change for human populations implied in the transition from a hunting-fishing-gathering economy to one based on domestication and food production. Nonetheless, the majority of the regional syntheses on a European scale published to date have dealt mainly with the historical narrative of the process, focusing on discussing the Neolithisation process from a demographic and/or cultural perspective. In this respect, the work of Ammerman and Cavalli Sforza (1984) without doubt constituted a turning point in a number of aspects relevant to the study of the Neolithisation of Europe and the Mediterranean. Applying Fisher's (1937) reaction/diffusion equation to the Neolithic expansion, they laid the foundation for current investigations of the expansion of livestock and agricultural farming on a continental scale. The absence of the principal wild progenitor species of domesticates (e.g., cereals and ovicaprines) in most of the European continent, and the available radiocarbon dates at the time, pointed to the Near East as their place of origin. Since then, and especially during the last 15 years, a growing number of interesting discoveries, surveys and excavations often carried out as a result of increasing urbanisation (a major issue in the Western

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European Mediterranean) have boosted a renewed interest in studying the Neolithic. This fieldwork has been complemented by an increasingly precise chronological framework, and provides a vital advance in accurately determining the timing of this process. The investigation of the Neolithic has been especially enriched through interpretative approaches, such as evolutionary theory, which go beyond a descriptive analysis of the data and concentrate on exploring the mechanisms and conditions involved in the framework of the cultural transition (Shennan 2008). At the same time, the development in other disciplines of new technologies has favoured the introduction of new methodologies in the study of territories, artefacts and ecofacts, giving rise to analyses that have enhanced investigation in this period. The genetic and isotopic analyses of ancient populations published in recent years deserve a special mention for their relevance to the consideration of demic impact and the coexistence of different socioeconomic traditions (e.g. Bollongino et al. 2013).

The purpose of this volume is to consider all these aspects from a multidisciplinary yet integrated perspective within the geographic framework of the Western Mediterranean. Why the focus on this particular geographic area? In the first place, the research boom in this area during past years, especially in specific areas such as the Iberian Peninsula, resulted in new ideas and perspectives that have not yet received sufficient recognition on a European and international scale in the overall syntheses on the Neolithic. The information on South-West Europe is often limited to a few general works (e.g. Guilaine and Manen 2007), which, while stressing the relevance of the study of the process in this region, do not touch on the numerous facets that characterise such a complex process of cultural and socio-economic change. During the twenty-first century various publications highlight new insights into the study of the Neolithic of the Western Mediterranean, but for the most part they are focused on specific regional syntheses and not readily incorporated into larger geographic frameworks (Ammerman and Biagi 2003; Robb 2007; Rojo et al. 2012; Manen et al. 2014; Pearce 2014). This volume provides an updated synthesis that allows us to explore the most notable aspects of recent investigations on the Neolithic expansion across the Mediterranean towards the southwestern corner of Europe. Rather than concentrating on descriptive aspects, our interest lies in showing and evaluating, from different analytical angles, the relevant data on which the hypotheses to explain the transition are based. This was the objective pursued with the organisation of the Symposium '*Novel Approaches to the Neolithic Transition in Western Mediterranean*' at the 7th World Archaeological Congress held at the Dead Sea in Jordan (14th–18th January 2013), and inspired the idea for this book.

The Mediterranean Sea constitutes one of the principal routes of the Neolithic expansion from the Near East into Europe. In its advance from the Adriatic region across the Italian Peninsula, the bulk of available information is concentrated on the European bank rather than the African coast, as a result of the fewer number of sites studied so far in the southern Mediterranean. Currently these information gaps do not allow for a detailed evaluation of the data, as emphasised in some of the chapters in this volume. In order to enhance our global comprehension of the process, recent investigations call for the development of exploratory studies in

North African regions (Linstädter et al. 2012). Although it is not yet clear what role North African farmers played in the spread of the Neolithic to the southern Iberian Peninsula, there is a real possibility that contact existed in western Mediterranean coastal areas between Neolithic communities from both North and South coasts (Manen et al. 2007). The work of Bernabó Brea (1950) constituted a turning point towards a global Mediterranean vision by recognising the links between the ceramic production in widespread areas from Italy, the North African coast, the South of France and the Iberian Peninsula. There are cultural links between both shores preceding the Neolithic, visible in Mesolithic hunter-gatherer blade and trapeze industries from the North African Upper Capsian, the Castelnovian in Italy and the south of France, and the Geometric Mesolithic in the Iberian Peninsula (García Puchol 2005; Binder et al. 2012; Rahmani and Lubell 2012; Juan-Cabanilles and García Puchol 2013; Marchand and Perrin 2015). During the early Neolithic, the cultural sphere of the impressed ceramics in the central and western Mediterranean also attests to this north-south connection (Guilaine 2001).

A maritime route for the spread of farming in the Western Mediterranean explains this contact between both shores, the supply and diffusion of obsidian, and the arrival of the Neolithic to most of the central-western Mediterranean islands. This route also allows us to better explain the swiftness of the process, as indicated by the available radiocarbon dates, in particular those samples that directly date the emergence of a production economy (Zilhão 2001). In this sense, at the end of the seventh millennium calBC we observe the first domestic plants and animals in southern Italy, and within a few hundred years domesticates are found on the southern coasts of France (in the early centuries of the sixth millennium cal BC), on the eastern coast of the Iberian Peninsula (in the mid-sixth millennium cal BC) and on the west coast of the Iberian Peninsula only 200 years later.

Associated with this swift expansion of farming is the so-called Neolithic package. This ‘package’ covers a whole series of technical innovations such as ceramics and polished stone, as well as the domestic plants and animals that will have a direct impact on nutrition, health, perception of changes in the dynamics of territorial occupation and exploitation, organisation of domestic areas and forms of social production, social dynamics and reproduction. Settlements are also a recurrent element, although taking diverse forms throughout the geographical area under study. Generally speaking they consist of domestic areas that incorporate common elements (houses, grain storage, graves, hearths and ovens) that imply a more permanent occupation of the village (Hofmann and Smyth 2013; Robb 2007). The discoveries made in the lacustrine settlement of La Draga (northeastern Iberia), discussed in Chap. 8, comprise well-preserved examples of tools and materials employed in daily life that help to define the characteristics of the aforementioned areas of production and consumption (Bosch et al. 2011; Palomo et al. 2014).

A common material culture element of the early Neolithic in the western Mediterranean is pottery impressed by using diverse instruments, among which the *Cardium edule* shell was employed in the decoration of numerous pottery vessels discovered from the Adriatic coast to Portugal and known as ‘cardial ware’. The variety of the forms and techniques of these ceramic containers observed across space and time evokes a shared background that can shed light on the forms of cultural transmission underlying the expansion of the production economy (Fugazzola et al. 2002; Manen et al. 2010; McClure 2011). These transmission processes can be explored through other components of cultural material (lithic tools), or through agricultural and farming practices, among other relevant features.

This point takes us back to one of the focal aspects of the Neolithisation debate: the interpretation of the process in terms of population expansion and/or transmission of information (demographic/cultural process). Traditional interpretations are based on the assumption that farming expanded into regions with a sparse hunter-gatherer population (Ammermann and Biagi 2003). These Neolithic 'colonies' expanded rapidly so that in the course of a few centuries agriculture and farming had spread throughout most of the western Mediterranean (Zilhão 2001; Guilaine 2013; Martí Oliver and Juan Cabanilles 2014). The few hunter-gatherer groups were integrated at varying rates, determined by the rhythm of assimilation or acculturation not yet clearly defined. In this interpretation, the Iberian Peninsula is so far best described by the 'dual model'—a combination of colonisation of farmers and adoption of food production by indigenous hunter-gatherers through acculturation into farming communities (Bernabeu 1997; Martí Oliver 2008). However, this interpretation of the process of Neolithisation is not without criticism. Other approaches minimise the initial demographic impact and emphasise the importance of cultural transmission through pre-existing Mesolithic social networks (Vicent 1997; Diaz del Rio 2011; Cruz Berrocal 2012).

Human-environment interaction during this period in the Western Mediterranean has also received renewed attention in the past decade, whereby the effects and environmental consequences of climate change acquire greater relevance in the discussion about patterns of territorial occupation between the last hunter-gatherers and the Neolithic spread (Berger and Guilaine 2009; Cortés et al. 2012; Bernabeu et al. 2014). To address these issues effectively, we need to progress in a number of areas. First, priority should be given to establishing the chronological framework and integrating demographic, environmental and economic data. It is essential to apply precise analytical techniques such as radiocarbon dating, ancient DNA and isotope analyses in order to obtain comprehensive information on kinship, diet, mobility or material provenance, among others (e.g. Gamba et al. 2012; Salazar-García 2012; Olalde et al. 2015; Salazar-García et al. 2016a, 2016b). These should be conducted alongside traditional study methods of materials, archaeobotany and zooarchaeology. The potential of recent novel microscopic (Power et al., 2015) and biomolecular (Warinner et al. 2014) analytical approaches on dental calculus will undoubtedly also widden the window to understand better past subsistence strategies, health and human-environment interactions.

Second, the exploration of mathematical and computational models is also of undoubted relevance, especially agent-based modelling (ABM) (Lake 2015). An interesting contrast arises also from the introduction of general theoretical approaches developed from physics to analyse socioecological dynamics, such as complex adaptive systems (CAS). This approach allows us to consider social processes as open, non-linear systems with emerging properties, functioning by rules derived from the theoretical framework of evolutionary theory (Barton 2013a). Applying this to the analysis of Neolithisation offers interesting results through virtual laboratories that reproduce the processes studied, allowing changes of condition under which these operated, and evaluating the results (Barton 2013b). Applying them to archaeological analyses constitutes a milestone for the discipline, providing it with a series of new methods and techniques for contrasting hypotheses. This happens by means of so-called generative models that derive from local scales or 'bottom-up' analysis, instead of general approximations based on observed phenomena, which are 'top down' (Lake 2015). Recent publications offer diverse examples of the use of mathematical (e.g. Pinhasi et al. 2005; Fort 2012; Isern et al. 2014) and computational models (e.g. Bernabeu et al. 2015; Lake 2015) in the investigation of the Neolithic expansion in Europe.

At the same time, various paradigms have been developed in evolutionary archaeology—which regards cultural evolution as an analogy of biological evolution—to study socioecological dynamics and cultural change by two major trends (Shennan 2008): those that prioritise the influence of natural selection on human behaviour (human behavioral ecology; e.g., Kennett and Winterhalder 2006), and those that emphasise the importance of development in our understanding of cultural changes (cultural transmission and the archaeology of cultural traditions, e.g. Boyd and Richerson 2005). The two perspectives allow us to contrast explanatory hypotheses regarding the processes and mechanisms of social evolution. In this regard, contributions to the analysis of the introduction of agricultural and farming practices are increasingly frequent, both on a general scale (e.g. Kennett and Winterhalder 2006) and with a specific attention to Europe (e.g. Downey et al. 2014; Shennan et al. 2015).

If we wish to address such a far-reaching process of change in human history as the appearance and spread of a production economy with objectivity and scientific rigour, then archaeologists must be willing to explore novel methodological and technological advances within a framework of testable theoretical perspectives. Taking advantage of methodologies from other sciences and humanities for the evaluation of processes of social, economic and cultural evolution will provide new insights into the dichotomy of demographic and cultural expansion, reflected in the customary models for explaining the Neolithic expansion.

This book presents the latest advances in the study of the Neolithic in the Western Mediterranean, with the purpose of integrating the results of the application of new techniques and theoretical paradigms in a work that includes a detailed update of archaeological, chronological, environmental, economic and demographic data. Our intention is to provide a synthesised, but also meticulous, perspective on the available information, arranged by theme in five sections. The contributions of noted specialists in different disciplines have greatly enriched the central idea of the book.

The first theme, '**New discoveries and new ideas about the Mediterranean Neolithic**', includes two chapters that introduce the reader descriptively into the appearance of agriculture and herding in the Near East and their expansion via the Mediterranean Sea. From the starting point of these new practices, Chap. 2 ('*The Neolithic Transition: From the Eastern to the Western Mediterranean*') gives an overview of the most current aspects of the investigation of the Neolithic in the

Fertile Crescent, and concentrates on its spread from the eastern Mediterranean (Cyprus, Crete and Greece) through to the south of Italy (Guilaine 2017). Moving the focus towards the Western Mediterranean, Chap. 3 (‘*New Approaches to the Neolithic Transition: The Last Hunters and First Farmers of the Western Mediterranean*’) introduces the debate about the appearance of the Neolithic in this area (demic/cultural model) by means of the analysis of current archaeological data, with special emphasis on radiocarbon dates published in recent years (Juan Cabanilles and Martí Oliver 2017).

The second theme, ‘**Reconstructing times and modelling processes**’, incorporates the latest developments concerning the chronological framework within two chapters. Chapter 4 (‘*Timing the Western Mediterranean Last Hunter-Gatherers and First Farmers*’) evaluates the radiocarbon data of the Neolithisation process in the Western Mediterranean, from Italy to the Iberian Peninsula (García-Puchol et al. 2017). In Chap. 5 (‘*Alternative Stories of Agricultural Origins: The Neolithic Spread in the Iberian Peninsula*’), agent-based modelling (ABM) explores different hypotheses regarding the Neolithisation process in Iberia, and unveils the potential of these new ‘virtual laboratory’ approaches for investigating social processes in the past (Pardo-Gordó et al. 2017).

The third theme, ‘**Landscape interaction: Farming and herding**’, includes a total of four chapters that present information regarding the environmental framework and relevant data concerning the characteristics of the first agricultural and herding practices. Chapter 6 (‘*Neolithic Human Societies and Woodlands in the North-Western Mediterranean Region. Wood and Charcoal Analysis*’) takes a diachronic view on the reconstruction of the vegetation and the economic practices related to the use of wood from the Mesolithic to the Neolithic based on charcoal analysis (Badal et al. 2017). Chapter 7 (‘*Evidence for Early Crop Management Practices in the Western Mediterranean: Latest Data, New Developments and Future Perspectives*’) characterises the beginning of agriculture on the basis of the available archaeobotanic data in the region (Pérez-Jordà et al. 2017). The following Chap. 8 (‘*Farming Practices in the Early Neolithic According to Agricultural Tools: Evidence from La Draga Site North-Eastern Iberia*’) explores the first agricultural practices in North-East Iberia based on the analysis of stone tools from the Neolithic site of La Draga (Banyoles, Girona) (Terradas et al. 2017). In Chap. 9 (‘*Farming with Animals: Domesticated Animals and Taxonomic Diversity in the Cardial Neolithic of the Western Mediterranean*’), attention is placed on herding practices, mainly on the introduction of domestic animals and their cultural and environmental impacts, by drawing on the zooarchaeological data from Cardial-Neolithic sites from Italy to the Iberian Mediterranean coast (McClure and Welker 2017).

The fourth theme (‘**Dietary subsistence of early farming communities**’) is comprised of chapters that focus on insights into subsistence from chemical analyses. In Chap. 10 (‘*Dietary Practices at the Onset of the Neolithic in the Western Mediterranean Revealed using a Combined Biomarker and Isotopic Approach*’) recent data resulting from organic residue analysis (ORA) to detect the contents of pottery vessels from various sites within the Western Mediterranean geographical area is discussed (Debono-Spiteri et al. 2017). Chapter 11 (‘*A terrestrial diet close to the coast: A case study from the Neolithic levels of Nerja Cave (Málaga, Spain)*’) combines isotopic and traditional methods to reconstruct the dietary patterns at Cueva de Nerja, one of the westernmost Mediterranean Neolithic sites (Salazar-García et al. 2017).

Finally theme 5, '**Human dispersal mechanisms and cultural transmission**', tackles a series of recent advances on the investigation of the initial demographic impact and cultural transmission linked with the Neolithic expansion. Chapter 12 ('*The Mesolithic-Neolithic Transition in Europe: A Perspective from Ancient DNA*') presents the current situation of the latest results of ancient DNA analysis carried out at Mesolithic and Neolithic sites, from a broad perspective that includes a synthesis of the data published in both the Near East and Europe (Fernández and Reynolds 2017). In Chap. 13 ('*Paths and Rhythms in the Spread of Agriculture in the Western Mediterranean: The Contribution of the Analysis of Harvesting Technology*'), the authors present an analysis of Neolithic sickles to propose a spatial and temporal interpretation of their variability, and establish models to interpret the diffusion of this agricultural technology (Ibáñez et al. 2017). Finally, Chap. 14 ('*Spatial and Temporal Diversity During the Neolithic Spread in the Western Mediterranean. The First Pottery Productions*') investigates mechanisms of cultural transition and explores quantitative methods by applying them to the study of cultural transmission associated with the decorative techniques of early Neolithic pottery in the wider West Mediterranean framework (Bernabeu et al. 2017).

The volume closes with a general reflection on the contributions presented in the different chapters by Stephen Shennan (2017) that aims to establish connections to aid our understanding of the phenomenon of the Neolithic expansion at a European scale.

The following pages offer new insights with regard to recent investigations in the study of the Neolithic of the Western Mediterranean. They include the very latest theoretical and methodological perspectives, as well as relevant biomolecular analyses for the evaluation of the appearance and expansion of a production economy in the study region.

We wish to here express our sincere gratitude to all the authors who contributed directly to this volume, and also all who worked on revisions and made the final product possible. Without their help it would have been very difficult to tackle this project. We hope that this volume provides a new vision of the socioecological dynamics of these societies, immersed in the profound and complex process of transition that constituted the Neolithisation process in the southwestern corner of Europe.

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Part I

New Discoveries and New Ideas About the Mediterranean Neolithic

Chapter 2
The Neolithic Transition: From the Eastern to the Western Mediterranean

Jean Guilaine

2.1 Introduction

When the Neolithic system reaches the Western Mediterranean region, it has already enjoyed a long history. In fact, if we consider that the first movements through the Strait of Otranto, from Greece or Albania to Southern Italy, occurred around 6000 cal BC, we can assume that the Neolithic emerges in the Eastern Mediterranean area two to three millennia prior to that. In this introductory paper we will review, first of all, the main traits of the Neolithic appearance in the driving zone of the Near East. It is a gradual phenomenon of mutation from the local epipaleolithic societies towards a production economy. Secondly, we will consider the problems linked to the diffusion of a new way of life into the Aegean region and the Italian peninsula, considering in particular Mediterranean Europe and the islands. We will omit the North African areas due to the incomplete nature of the documentation, except with regard to the western extremity, Morocco. In each area we will focus on the time of arrival, this being the main theme of the present work.

The Levantine Middle East with Southeast Anatolia is now the oldest epicenter of the "Neolithic Revolution." The Chinese focus seems to be independent and probably in a similar chronological framework with the Middle East, although the dates there are a little more recent. Although the first manipulation of plants in the Mexican area is equally early, their successful domestication does not present the same antiquity as in Southwest Asia.

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2.2 The Levantine Middle East and the Southeast Anatolia

Middle East neolithization is a gradual process. It is considered that the first step consists of the sedentism or (sub-sedentism) of the epipaleolithic Natufian people, which commences around 12,000 cal BC. This settling is relative because mobility also persists among the Natufians. The more stable dwellings are circular or semicircular and partially subterranean, with stone foundations and a structure of wood or lighter materials. The average diameter of the most ancient Mallaha houses is between 5 and 7 m (Valla 2000). A wide range of animals are hunted: gazelles, fallow deer, roe deer, aurochs, hares, reptiles, turtles, and fish. Cereals, legumes, and fruits are gathered, and there is evidence of the presence of domestic dogs. Another important factor of these early settlements is the presence of individual or collective graves in or near the dwellings, indicating a desire to keep their dead close to them.

A cooler climate resulting from the Younger Dryas (ca. 10,800/10,000 cal BC) may have generated a return to mobility, including the first dispersion of human groups by sea. Nonetheless this possible destabilization does not seem to have put an end to the settling process in motion since the Khiamian phase (towards 10,000/9500 cal BC), a period characterized by the development of projectile points with lateral notches, the El Khiam points, which persist throughout the pre-pottery "Neolithic A" phase (PPNA) (9500/8500 cal BC).

During this period round houses can be identified in the larger valleys: the Jordan (Jéricho, Netiv Hagdud, Gilgal I) and the Euphrates (Çayönü, Mureybet, Jerf el Ahmar). Their presence is also recognized in the more desert inland territories (Wadi Tumbaq 3 in the Ba'las) (Abbes 2014). We find them in Eastern Jezirah (Nemrik) and in the Zagros (Aurenche and Kozlowski 1999). Brick and mud are sometimes combined with stone in construction, and barns and silos are apparent. The first attempts at cultivation of wheat and barley are observable around 9000 cal BC, although it is not usual to see clear modifications in the seed morphology, leading botanists to speak of "pre-domestic" agriculture (Tanno and Willcox 2012). The meat diet is still based on hunting activities, and these newly settled peoples are sometimes called "cultivator-hunters." After this "public" buildings—often very large—begin to be used, with varying functions: economic (barns), social (places for meetings and decision-making), or ceremonial (for rituals). They are referred to as "collective" or "community" buildings to emphasize the unifying role they could play on a village level. Some of the best examples are Jericho's tower, the Jerf el Ahmar "pit" buildings, the frescoes building in Djadé or the Gobekli hill "sanctuaries," which are characterized by megalithic carved stelae in their walls or centers with an iconography clearly evocative of wild or dangerous animals (Stordeur 2014; Coqueugniot 2014; Schmidt 2006).

Towards 8500 cal BC, several sites progressively show the presence of domestic cereals. At the same time the domestication of ungulate animals commences—goats, sheep, cattle, and pigs—as these are subjected to an increasing human control. The ninth millennium cal BC also turns out to be the key period for mutations to a full Neolithic. Towards the end of the PPNA, there are architectural transformations, as can be seen in Jerf el Ahmar: the houses increasingly show oval, apsidal, or quadrangular designs. They are built on ground level and sometimes benefit from internal divisions, although some "community" buildings continued to be built in "pits," using the traditional circular design (Stordeur 2014). Rectangular structures will eventually predominate and become one of the cultural traits of the PPNB (Pre-Pottery Neolithic B: 8500/7000 cal BC), although traditional round buildings do not completely disappear. Çayönü (Turkey) has a number of buildings distributed through time that show successive adaptations to ensure greater comfort for the occupants: raised floors, "caves" or storage rooms, independent rooms, etc. In these villages, the original public buildings continue to assume ceremonial or cultic functions, such as the "Cult Building" of Nevali Çori or the "Skull Building" of Çayönü (Özdoğan and Başgelen 1999). The development of a particular sculpture (cf. Yeni Mahalle, Turkey), using male and female figurines and a variety of "signs," becomes part of a symbolic system related to social activity.

Throughout the eighth millennium cal BC large agricultural villages begin to appear, some even exceeding ten hectares (Abu Hureyra, Syria). The hierarchical connection between settlements increases, from larger settlements down to minor sites. In the arid zones on the outskirts of cultivated areas, a more mobile lifestyle continues with pastoral camps (late PPNB). Despite regional variations, a vast cultural sphere arises, dubbed "PPNB Koiné" by O. Bar Yosef, stretching from the Neguev to the Anatolian plateau and to Southern Iran (Bar Yosef 2006). The PPNB points out a wide use of certain techniques, such as blades created by bipolar reduction on naviform cores. Some specialized knappers demonstrate high-level skills in this field, such as the obtention of obsidian blades from bipolar cores, in the style of Kaletepe, Anatolian plateau. These artifacts of Cappadocian origin are then exported over more or less long distances, helping to strengthen liaisons within the PPNB sphere. The cultural coherence of this sphere is strengthened by an extensive use of various objects (bracelets, stone dishes, shells), as also occurs through the development of certain varieties of arrowheads.

The internal organization of this society is still under debate. Key families could be responsible for the administration and hierarchical organization of particular sites, and their authority denoted by the possession/distribution of valued articles. They might also assume responsibility for the rituals carried out in the ceremonial centers, thus wielding a form of "intellectual" power and promoting social integration. Individuals in possession of certain strange distinguishing objects have been identified, such as those possessing copper necklaces in Halula (Syria) in the eighth millennium, this being a metal employed at the time for making ornaments or rudimentary instruments. Some of these are children, presumably from notable families; but there is also a man wearing a copper pendant decorated with Anatolian chalcedony beads, turquoise, and quartz, who could have been an important personality (Molist et al. 2009). These considerations are still speculative.

Towards 7000 cal BC, the "PPNB koiné" breaks down into regional units of more limited extension. This trend is perceived by some authors to be gradual, but considered sudden by others. In addition to the previously used basketry, ceramics appear both on the coast (several facies of pottery decorated with impressions develop from Cilicia to the Lebanon) and in the Euphrates and Tigris valleys. The tendency is apparent a little later in the south of the Levant, with the advent of the Yarmoukien towards 6500 cal BC. The seventh millennium cal BC will be that of the exodus towards the Mediterranean, in particular towards the Aegean Sea and islands, although the Neolithic had already been present in Cyprus for several centuries.

2.3 The Cypriot Neolithic: A History in Stages

In the maritime Neolithic diffusion from the Middle East towards the West, Cyprus is indeed a special case. The proximity of the island to the mainland (±80 km) made it quite accessible, and early epipaleolithic continental explorers would soon become aware of the island's potential for food production and raw materials. Some place these early incursions in the Younger Dryas, when the cold and arid climate could have spurred the search for new territories to exploit. The earliest testimony to these visits is found in the second layer of the Aetokremnos rockshelter, in the southern part of the Akrotiri peninsula. It is dated back to 10,000–9500 cal BC. Two other coastal sites (Aspros and Nissia Beach) are often considered the oldest on the basis of their lithic industry, but in the absence of faunal remains and conclusive dating their chronology needs to be clarified. The idea that these early visitors contributed to the extinction of the relict fauna of dwarf hippos and elephants is supported by A. Simmons, excavator of Aetokremnos, but rejected by others who feel that this disappearance is older and due to natural causes (Simmons 1999). On the contrary, these newcomers introduced a continental species, a small pig, that became during the subsequent centuries the island's only hunted mammal. Other observable fauna are birds, mollusks, amphibians, and reptiles.

During the later phase of the continental PPNA—between the end of the tenth millennium and 8600 cal BC—the first real sedentary settlement of the island was established, taking the form, as on the mainland, of "cultivator-hunter" sites. Emmer is introduced and cultivated while protein largely proceeds from the wild pigs. The two sites known to date (Asprokremnos-Agia Varvara and Klimonas-Ayios Tychonas) have circular houses delimited by a foundation trench or excavated in the substratum; at Klimonas their diameters vary between 3.1 and 7.3 m. At the center of this site there is also a larger circular construction of 10 m in diameter, housed in a large pit and surrounded by a mud clay wall. This is clearly a "community" building of a type known in the Euphrates PPNA and its function could be multiple: economic, social, and ceremonial (Vigne et al. 2012). This combination of central building surrounded by detached houses is not an autochthonous invention, but a model designed on the continent and transferred to the island by immigrants from the mainland. Similarly, the lithic techniques used for knapping high-quality local flint resemble Levantine examples: unipolar cores from which blades, sometimes used as sickles, are carved. The weapons are original: they are sharp and often present a short tang, whereas the Asprokremnos models have a bifurcated basis. The abundance of projectile points indicates regular hunting, and perhaps also conflicts inherent to the first territorial delimitations. Picrolite, a local green stone, is used for making ornaments.

Towards 8500/8400 cal BC, in the early PPNB, the neighboring site of Shillourokambos in Parekklisha was founded, either by descendants of the first immigrants or by the arrival of a new wave. The period through to 8000 cal BC boasts an architecture which combines wooden poles with clay (Shillourokambos, Tenta V). There are circular houses and palisade enclosures, the latter no doubt pens for the animals lately introduced: cattle and goats, species already domesticated on the mainland (Guilaine et al. 2011). Some of these goats possibly returned to the wild, giving rise to a later autochthonous re-domestication (Vigne 2014). Some domestic pigs could also have been introduced to the island, as well as cats and "domestic" mice. Wells for obtaining water are dug down to the phreatic levels (Mylouthkia, well 116, Shillourokambos, well 2, 66, 310, 431). The lithic industry sees the introduction of bipolar reductions on naviform cores, and the blades thus obtained are often used to make good sized projectile points. However, there are fewer of these than in the previous period: less hunting and a higher proportion of the meat intake now provided by herding? Obsidian from Cappadocia is imported in the form of blades knapped by pressure, and stone dishes are developed from limestone or hard rocks. Agriculture is still based on emmer, but a form of wild barley is also harvested.

Towards 8000 cal BC, stone houses appear at Shillourokambos, and some kind of "proto-bricks" are involved in their construction. The house floors are hardened, and a large flattened area is noted (a plaza?). At this point domestic sheep are introduced, as well as a wild species, the Mesopotamian fallow deer, which will be actively hunted for centuries. From now on barley is cultivated along with wheat, and grinding objects are more and more numerous. Changes appear in the lithic tools: sickles are now composed of segments showing the gloss characteristic of grain harvesting. Small at first, these segments become bigger as time goes on. Obsidian imports are at their maximum between 8000 and 7500 cal BC. More wells are dug. This phase is contemporary with the middle PPNB in the Middle East.

A marked turning point is apparent at Shillourokambos around 7500 cal BC (late PPNB). First in lithic tools: the beautiful translucent flint used since the PPNA (Klimonas) is somewhat neglected in favor of a lower quality opaque chert whose sources are located closer to the site. More robust tools are created with this new raw material: picks, scrapers, and (at best) elongated and broad blades. Bipolar core reduction declines and disappears. Obsidian imports from the mainland drop abruptly, but stone vessels experience a greater diversification, and a varied artisan craftsmanship appears using picrolite: micro-bowls and pots, and pieces of diverse shape decorated with fine striped patterns, or with anthropomorphic or animal motifs. The settlement is now a hamlet of a dozen or so small, circular houses built on flattened earth. These will be replaced, after 7200 cal BC, by larger circular buildings with stone foundations. The activity areas—flag stone work tables, hard threshing floors, hearths—are located outdoors, indicating a communal rather than private nature. Following a decrease in ovine breeding, new sheep species are introduced. One particular tomb holds a man surrounded by some singular objects: polished axes, ochre balls, blades, marine shells, and a (probably domestic) cat.

In the same period, the neighboring site of Kalavasos-Tenta is a small, hill-top village surrounded by a dry stone wall. It has circular houses built with stone or mud bricks. Throughout the several centuries of site occupation a large community building is in use, following the tradition of PPNA buildings (Todd 1987). At its largest it reaches 12.30 m in diameter. Wells are still in use (Mylouthkia 133), and there are even big tanks (Shillourokambos).

In the seventh millennium cal BC, the Cypriot pre-ceramic Neolithic continues to evolve, the key site being Khirokitia, similarly protected by a wall which, at a later date, is moved and realigned. The circular houses are always of stone and mud-brick, with walls reinforced by outer rings and flat roofs. The absence of internal space divisions suggests a complementary operation between several of these buildings, often grouped into nuclei. Some are of considerable duration, probably in connection with the history of important families, and are the object of frequent alterations. Graves located under the floors of houses strengthen the notion of identity and permanent family residence (Dikaios 1953; Le Brun 2002).

This Neolithic, still without ceramics, may have lasted to the beginning of the sixth millennium before completely disappearing for unknown reasons, after which a documentary hiatus occurs. A new agricultural settlement on the island emerges around 4800/4500 cal BC linked to a new Neolithic culture, the Sotira, this time with ceramics.

It is therefore apparent that the Cyprus Neolithic is a very long process that lasts throughout the history of the Middle East pre-pottery Neolithic (Guilaine and Le Brun 2003; Peltenburg 2003). It ranges from the introduction of pigs in the Epipaleolithic, and the early appearance of agriculture in the PPNA (circa 9000 cal BC). Then, throughout the whole PPNB (8500/7000 cal BC), we witness successive arrivals of continental waves bringing, at one time or another, oxen and goats (around 8500 cal BC) and then sheep and fallow deer (about 8000). The island seems then to show some rejection of the mainland experiences. Houses remain circular, following the PPNA tradition. Ceramics only appear much later, into the fifth millennium cal BC, considerably after Greece or Italy. It is therefore difficult to regard the island as a transferal point in the geographical distribution of the Neolithic towards the West. Its story is unique.

2.4 The Anatolian Diffusion

Having described the Cypriot parenthesis, we need to return to the Middle East to better understand the Neolithic diffusion process towards the Central Mediterranean. In the eighth millennium cal BC, the Neolithic, although still at a pre-ceramic stage, had already reached its culmination: villages, agriculture, and livestock formed a coherent system. The appearance of pottery in the northern Levant and Central Anatolia around or shortly before 7000 cal BC completed the "Neolithic package" that would extend the agricultural way of life towards the West. This diffusion was by land and sea simultaneously. The analysis of the latter route receives the priority in this article, but keeping in mind the parallel terrestrial process.

In the center of Anatolia, the PPNB can be seen in Penarbaşi and Aşikli. At Aşikli, it is characterized by a system of quadrangular houses grouped together and associated with a complex of possibly "public" monuments, but without the architectural and artistic emphasis seen at the Euphrates valley sites. The pre-pottery Neolithic is unknown further west, and it is evident that this area constitutes a cultural frontier at this point in time. The pre-ceramic which will mutate on site into the ceramic phase (Özdoğan and Başgelen 1999; Özdoğan et al. 2013). In this way the model of terraced houses built of brick, with flat roofs, will continue at Çatalhöyük in the Konya plain, a site dated between 7400 cal BC and the end of the seventh millennium cal BC. The decoration of walls with paintings or molded motifs occupies a significant place here, and human remains have been found buried under some of the houses (Mellaart 1967; Hodder 2006).

The question arises to what extent Anatolia was involved in the neolithization of mainland Greece, and by which routes (Halstead 2011). In general, we observe that the transfer to the agricultural way of life occurs in the Mediterranean and Europe in a changeable cultural context. Some objects manufactured in the original areas continue to be produced during the propagation, but others undergo transformation. Still others will be discarded but not necessarily forgotten so that they subsequently reappear further west, with certain alterations, demonstrating the cultural memory of the migrants. But this does not rule out regional creativity, especially when it is revealed by the choice of identities distinct both from the place of origin and from the neighboring areas.

These variants affect not only the material production but also the village plans, architectural models, funerary practices, and symbolism, so that we cannot speak of a standard model of Mediterranean Neolithic (Guilaine 2003), but of a degree of variability in every major cultural sphere (PPNB zone, Aegean, Western Mediterranean). For this reason, the transmission and remobilization of ideas and techniques respond to complex processes that archaeologists can often barely decipher.

The Anatolia-mainland Greece relationship is a case in point with regard to this kind of problem. The earliest manifestations of the "Neolithic" package as it occurs in eastern Thessaly are mainly concentrated in villages scattered across the plain, indicating a limited and selective colonization (Early Neolithic: 6500/5800 cal BC) (Perlès 2001). The package includes a panoply of grains (einkorn, emmer, barley) and domestic ungulates (goats, sheep, cows, pigs) whose origin is now unanimously regarded as exogenous. Those archaeological records which give some indication of origin point invariably towards Turkey. The first ceramic horizons (Monochrome, Protosesklo), mainly vases with bases, are succeeded in a second phase by more varied ceramic shapes, often with painted sides (Sesklo). This is observable taking an overall view of Anatolia; however, a more detailed study does not readily reveal close similarities. We find similar forms in western Anatolia (Höyücek) or Northwest Turkey (Early Fikirtepe, Hoca Çesme), but it has not been conclusively demonstrated that these sites predate those of the Thessalian villages (Özdoğan et al. 2013). However we now know that a former Neolithic, dated to the second half of the seventh millennium, has been discovered at Dikili Tash, Eastern Macedonia, a region with no previous record of sites from this period (Lespez et al. 2012). This revives the idea of mainland Greece being colonized from Turkish Thrace. In central Greece and the Peloponnese the same monochrome pottery horizons or "Rainbow Ware" are early Neolithic. Similarities with Anatolia of a more general nature could also be found in various other objects: some obese figurines holding their breasts (Höyücek/Sparta, Nea Nicomedia); some conical or sub-rectangular seals (Çatalhöyük/Sesklo, Nea Nicomedia); the "altar tables" (Höyücek/Sesklo); and the use of bone hooks (Çatalhöyük/Soufli Magoula). We know that the use of bricks for building, present in Anatolia, is also confirmed in several Aegean localities alongside wooden and mud houses, although only the latter exist in higher latitudes.

However, there is also no shortage of differences: the absence in Greece of the kind of close-grouped village seen at Çatal, and instead a looser arrangement of houses; the lack of the exuberant wall art characteristic of Central Anatolia; divergences in the shape of some Greek figurines (elongated necks or "coffee bean" eyelids), if contrasted with the Turkish models. Similarly pointed weapons or daggers known in the Anatolian PPNB tradition do not "pass" into Greece, where the ancient Neolithic is characterized by transversal pointed arrows.

2.5 The Southern Aegean and Crete

Being a world of islands, the southern Aegean could hardly be neolithized by any other via than the sea. Navigation, it is true, was well known since Epipaleolithic times and probably maritime networks were already in place. In the eleventh millennium cal BC, Melos obsidian had been exploited and brought to the continent (Franchthi Cave) (Perlès 2001). Both Epipaleolithic and Mesolithic sites have been reported on various Greek islands (Crete, Gavdos, Lemnos, Corfu). The clearest example is the site of Maroulas on Kythnos, in the Cyclades (Sampson et al. 2010). Thirty-one circular structures, some of them elliptical, 3–4 m in diameter, with pavements and a peripheral edge of standing stones, were identified there: they are interpreted as remains of houses. Twenty-five burials in pits, outside the aforementioned structures or placed under the house floors, have been recorded. Radiocarbon dates place the site between the late ninth and early eighth millennium cal BC. Although local quartz is the dominant raw material (80%), Mélos obsidian is used in 17% of lithic tools. Interestingly, we note the presence of two species whose introduction may be anthropic: domestic dogs and some pigs. So we find here, after a slight time lag, a behavior with regard to the transfer of wild animals (a wild boar) similar to that observed in Cyprus.

The site of the Cyclope cave in Youra, an island of the Sporades, was occupied during two phases of the Mesolithic, first in the ninth millennium cal BC, then in the seventh (Sampson 2008). Although the economy of the populations is largely oriented towards the exploitation of the marine environment (fish, shellfish), the presence of a small swine is also recorded, as is that of a goat of robust constitution. These wild animals could be transferred to the islands under human control.

Crete has recently revealed the presence of a number of Mesolithic sites (Strasser et al. 2010). However, it is around 7000/6800 cal BC that the Neolithic appears there for the first time, a few centuries earlier than in Thessaly. The presence of wheat and peas cultivators and goat, sheep, and oxen farmers is attested at the lowest level of the stratigraphy at Knossos. Curiously pottery is unknown, while the use of mud bricks in construction is a sign of a continental technique introduced into the island. Where did this pre-pottery Neolithic arise? We can hypothesize about an Anatolian origin and a movement via the island "bridge" of Karpathos. However the lithic tools, made of 30% of local rocks and 70% of Melos obsidian, seem to fit into the indigenous Mesolithic tradition (Kaczanowska and Kozlowski 2011). Knowledge borrowed from elsewhere by the indigenous people?

This first colonization of the island did not last long. A chronological gap in the stratigraphy of Knossos shows that the Aegean Early Neolithic period (6500/5800 cal BC) is only represented by occasional occupations. Settlers will not come back here until the Middle Neolithic, halfway through the sixth millennium cal BC (Evans 1964, 1968; Efstratiou et al. 2004). This is why the expressions of "Early Neolithic I and II," sometimes used to designate the period immediately after the Pre-Pottery Neolithic horizons, are incorrect because it is actually a Middle Neolithic. Admittedly this stratigraphy includes a hiatus of several centuries between the aceramic horizon and subsequent occupations.

2.6 From the Aegean to the Adriatic

Western Greece is an interesting geographical area for our purpose. It is here that the Aegean Neolithic gives way to the impressed ware groups that will ensure the Neolithization of both sides of the Adriatic and the Western Mediterranean zone, making it a region where a cultural mutation transpires.

A first consideration is the Mesolithic/Neolithic transition. In the Peloponnese, a model was proposed based on the evolution observed in the Franchthi cave. At the end of the eighth millennium cal BC, the final Mesolithic includes an industry using retouched flakes, notches, denticulates, and end-scrapers. To these we can add, as well as some geometric trapezes obtained from flakes, numerous microliths which seem unorthodox when compared with typical Mesolithic "geometrics" in Europe, being small flakes of diverse forms, locally retouched. These tools would be a continuing tradition in the following horizon known as "initial Neolithic," dated around 6700/6600 cal BC (Perlès 2001, 2003). As in Knossos, this period here is aceramic, but goats and sheep are well documented alongside cultivation of emmer and couplet barley. These indications of an initial food production do not put an abrupt end to predatory activities: the gathering of shellfish, for example, continues. The real transition will arrive with the implementation of the Early Neolithic which will introduce, in addition to the now essential production economy, a series of new elements: polished axes, grinding stones, ceramics, and spindle whorls.

This constitutes the same type of evolution as has been proposed for the site of Sidari in Corfu. The excavations conducted by A. Sordinas in the 1960s revealed the following sequence (Sordinas 1969, 2003):

- A "Sidarian" Mesolithic that is especially characterized by non-geometric microliths on small shaped or truncated flakes, geared towards the exploitation of marine resources.
- An "initial Neolithic" in direct relationship with the previous stratigraphic horizon which continues the lithic tradition. The presence of domestic species (ovine and caprine) are registered and, unlike in the Franchthi cave, ceramics. These appear to be baked insufficiently or at low temperature, poorly elaborated and with original incisions for decoration (Sordinas 1969). The impression given is of an acculturation of the Mesolithic group.
- An Early Neolithic, clearly defined, characterized by the presence of impressed ware of the Italian-Adriatic type.

In 2004, a new field investigation took place at the site, led by G. Metallinou, giving rise to a new program of studies. The profile of the second investigation was some 15 m behind the first, and the two excavations are not completely comparable; nonetheless as the radiocarbon dates of the early research were prejudiced by excessive standard deviations, they were completely revised in the new analysis program, with the following results (Berger et al. 2014):

- "Sidarien" Mesolithic in revised position, dated around 7100/6600 cal BC.
- "Initial" Neolithic, in place, dated at 6450/6220 cal BC.
- Early Neolithic with *ceramica impressa* dated at 6050/5960 cal BC.

With this new timeline, we can conclude that the Corfu "Initial Neolithic" fits well into the Aegean Neolithic (second half of the seventh millennium cal BC). It is characterized, in the recent excavations, by monochrome ceramics. Moreover, the following Neolithic, with the impressed pottery, is in complete chronological agreement within the time frame of the Adriatic-Italian impressed ware archaic phase. The 2004 research did not accept the validity of the famous "underbaked and incised" ceramic of the 1960s "initial Neolithic." This period is only characterized by undecorated pottery.

In contrast, the revision of the Sordinas materials shows, for this initial Neolithic, that the "coarse" and incised ceramic of this horizon was only one component of the set. It also contains a well baked "monochrome" component, which forms a good match with the contemporary undecorated pottery horizon of mainland Greece. This leads us to the—at least provisional—conclusion that the neolithization of the western coast of Greece first surfaces in the second half of the seventh millennium cal BC, and gives place around 6000 cal BC to the impressed ware horizons that will ensure in their turn the neolithization of the Adriatic coast and the Italian peninsula.

2.7 The Opening of the Adriatic, Italy and Beyond

In the central Mediterranean, in the last centuries of the seventh millennium cal BC a mutation of “monochrome” into “Impressa” takes place. The impressed ware culture arises in the geographical area of West Greece and Southeast Italy, which is where the oldest well-dated sites have been found. What are the bases of this culture? This is a difficult question, because the potential of the Mesolithic substrata differs from one side of the Adriatic to the other. The “Sidarien” non-geometric microliths (without microburins) and, more generally, the Aegean Late Mesolithic characterized by small flakes contrast with the Castelnovian complex, in southern Italy (Dini et al. 2008). It is not certain that the potential Mesolithic legacies are at the foundation of all the lithic components of the first impressed ware Neolithic. In fact, it includes new elements (long blades of flint, glossed bladelets, polished axes) whose origins are to be found in the full Neolithic horizons of the Aegean area (Guilaine and Cremonesi 2003).

Meanwhile, the question of the genesis of decorated ceramics, which in this region of the Mediterranean replace the monochrome pottery, continues to be controversial. Some see it as the result of population movements from the Middle East, where impressed ware horizons are known (Bernabo Brea 1950). Others believe that its origin is to be found in the Balkan ceramics decorated with impressions. The most logical conclusion is to accept an autochthonous origin, on both sides of the southern Adriatic, followed by a rapid diffusion process along the coast of Dalmatia, Southern Italy, and Sicily. At a time when ideas seem to circulate freely and extensively, we should not underestimate contacts that may have occurred in the southern Balkan area. For example, the practice of “burned houses,” deeply rooted in Balkan Europe, is also found at South Italian Neolithic sites such as Favella (Tiné 2009).

The dynamism of this area will become a new trigger that results in the Neolithic expansion towards the northwestern Mediterranean. We now know that this process was accomplished in two stages:

- A primary distribution of the “leap frog” type, led by small pioneering units with a well-established agro-pastoral economy, found in several Western Mediterranean sites: Sicily (Kronio), Tuscan Archipelago (Isola del Giglio), Liguria (Arene Candide), Provence (Pendimoun), Languedoc (Pont de Roque Haute, Peiro Seignado), Valencia (El Barranquet). This takes place between 6000 and 5600 cal BC (Guilaine et al. 2007).

- A secondary phase of generalization and regional settlement that will see the development, in certain geographic areas, of specific Early Neolithic cultures: Stentinello in Sicily and Calabria, Tyrrhenian Cardial in Latium-Tuscany-Sardinia-Corsica, regional groups of the Franco-Iberian Cardial (Provence, Catalonia, Valencia, Andalusia). (Manen et al. 2014)

It is regrettable that the documentation available to date does not allow us to clearly describe the steps and aspects of the Neolithization along the Mediterranean fringe of the African continent. In the Egyptian Delta, the introduction of the agro-pastoral economy from the neighboring Middle East does not really occur until 6000 cal BC, and it is during the course of the sixth millennium that it seems to appear in Libya (Haua Fteah). There is clearly a rapid extension along the coastline, since wheat and sheep, species of oriental origin, are in evidence in this same sixth millennium cal BC at the Cardial site of Kaf That El-Ghar (Morocco) (Ballouche and Marinval 2003). It is as yet impossible to know what interactions took place between the European and African Mediterranean shores. The potential role of the Sicilian Strait, where the two continents are closest, deserves special attention.

2.8 A Matter of Timing?

The spread of the Neolithic throughout the Mediterranean is therefore a complex phenomenon that combines rapid movements into isolated and sometimes temporary locations, with a slower but more geographically extensive consolidation process. Also, this neolithization does not generate a standard culture, but a creative process that keeps changing with the passage of time. Despite the variety of Neolithic cultures in place, taking a panoramic view we can consider that there are three major cultural regions in development: (1) the oriental Neolithic pre-pottery region, which is the system's foundational region; (2) the Aegean-Anatolian region with its diverse cultural variants; and, finally, (3) the region of impressed ware groups in the Western Mediterranean zone. As we have said, the African coasts are insufficiently investigated to know whether or not the spread of the Neolithic there is the result of a single cultural sphere. The information so far available (the first Fayum Neolithic, the Neolithic of Capsian tradition whose revision is necessary, and the Moroccan Cardial) argues for some kind of diversity, but a more accurate analysis of both common traits and differences of identity is needed.

2.9 A Summary of the Chronological Framework

1. The original period of the Eastern Pre-Ceramic (PPN) takes place from 9500–8500 cal BC (PPNA) (Fig. 2.1), a millennium that sees the first steps in the domestication of cereals. Then, during the early PPNB (8500/8000 cal BC), the domestication of ungulates takes place, and the impact of these creative spheres extends from the Southern Levant to central Anatolia (Fig. 2.2). This

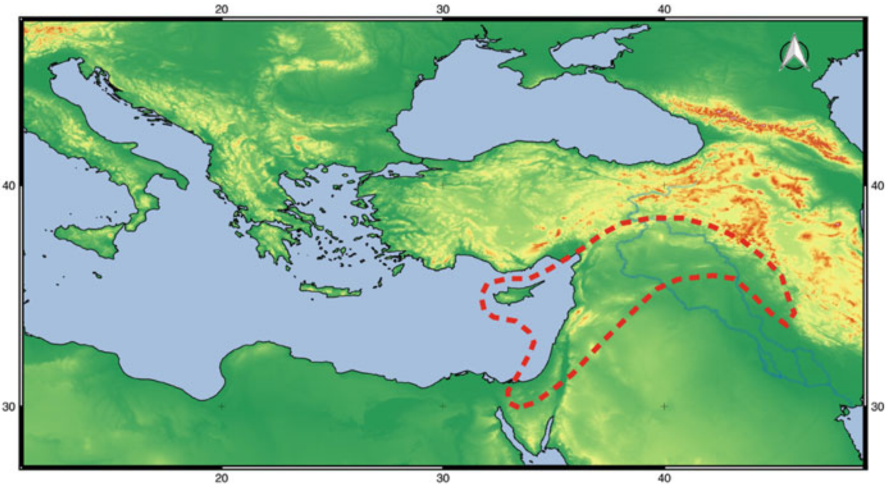

Fig. 2.1 PPNA sphere (9500–8500 cal BC)

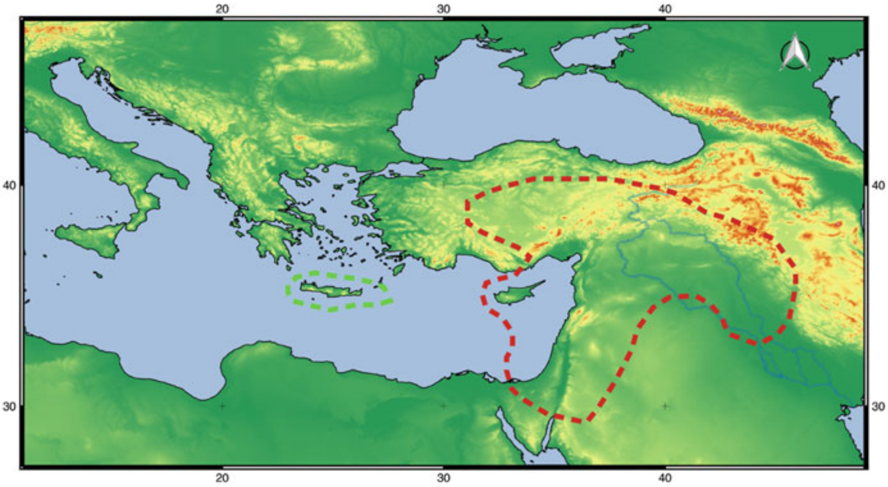

Fig. 2.2 *Red line*: PPNB sphere (circa 7000–6500 cal BC). *Green line*: Cretan "a-ceramic" (circa 7000–6500 cal BC)

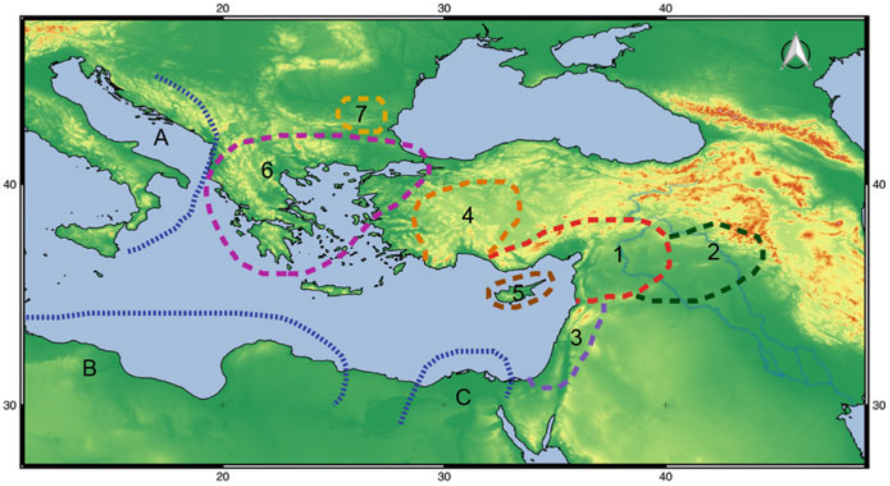

Fig. 2.3 Mediterranean in the second half of the seventh millennium cal BC (6500–5600 cal BC). (*1*) DFBW (dark faced burnished ware) and Proto-Halaf; (*2*) Proto Hassuna; (*3*) Yarmoukian; (*4*) Anatolian Early Neolithic (Catal Huyuk/Hacilar); (*5*) Khirokitian (a-ceramic); (*6*) Monochrom Early Neolithic (Hoca Cesme, Proto Sesklo); (*7*) Kovacevo/Karanovo I. *Blue line*, last hunter-gatherers: (*A*) Castelnovian sphere, (*B*) Capsian sphere, (*C*) Egypt

important cultural complex is confined within those boundaries. This is followed by a pause, after which the Neolithic is regenerated by the invention of pottery in the period 7400–7000 cal BC.

2. The complete "package" of Neolithic elements then conquers the western part of Anatolia and the Greek region, between 7000 and 6400 cal BC (Fig. 2.3). Its presence is noted in Crete around 7000 cal BC (in a-ceramic version), around 6500 cal BC in Thessaly, and around 6400 cal BC in Western Greece, all these dates indicating a fairly rapid diffusion process, after which comes a second pause lasting two to three centuries.
3. The "impressed ware" cultures are developed around 6000 cal BC in the Ionian Sea, and constitute the major factor in the Neolithic "package" which moves on to conquer the West (Fig. 2.3). Towards 5700 cal BC Neolithic pioneers are found in Southern France, and by 5600 cal BC in Spain, less than four centuries after their arrival at the Southern Adriatic area. Around 5600/5500 cal BC, Cardial groups gain pride of place in the northwestern frontier areas, and about this time Morocco is taken over, either from Spain or via the African coast.

In conclusion, in no more than 1500 years the Neolithic spreads from central Anatolia to the Iberian Peninsula. Admittedly, if we consider the time span between the first agriculture, around 9000 cal BC, and its appearance in Spain around 5600 cal BC, the delay is more significant (±3500 years).

The neolithization of Mediterranean Africa occurred much later, no earlier than 6000 cal BC in Egypt, but its progress is swifter. In less than a 1000 years, towards the end of the sixth millennium cal BC, wheat and sheep have already reached Morocco. We can therefore measure to what extent the Neolithic diffusion around the Mediterranean experienced a rapid propagation, occasionally halted by regenerative pauses, all of which can be best interpreted using an arrhythmic model (Guilaine 2003, 2013).

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Chapter 3
New Approaches to the Neolithic Transition: The Last Hunters and First Farmers of the Western Mediterranean

Joaquim Juan-Cabanilles and Bernat Martí Oliver

3.1 Introduction

The identity of the first Neolithic groups in the West-European Mediterranean constitutes, as in other areas, a much-debated subject in studies about the Neolithic transition. This is linked with the discussions generated by the two contrasting neolithisation models within the diffusionist camp: the demic model and the cultural model. In the Western Mediterranean region the appearance of the Neolithic, understood as the presence of food production based on agricultural and husbandry practices—and the associated technological innovations of pottery and polished stone tools—can only be explained from a diffusionist viewpoint, due to the Near East origin of the first domestic species (wheat, barley, sheep, goats, etc.). This has been further confirmed by genetic analysis of those European species (goats, cattle, pigs) with wild ancestry (e.g. Bruford et al. 2003; Fernández et al. 2006; Edwards et al. 2007; Larson et al. 2007; Naderi et al. 2008; Zeder 2008; Vigne 2011; Larson and Burger 2013).

The demic model is obviously founded on phenomena of population expansion such as colonialism and pioneering, a perspective widely shared regarding the Western Mediterranean territories (e.g. Zilhão 1997, 2001; Bernabeu 1997, 1999; Binder 2000), drawing from the classic 'wave of advance' model described by Ammerman and Cavalli-Sforza (1984, with previous literature), and qualified by the idea of an 'arrhythmic spread' (Guilaine 2000–2001). The cultural model, on the other hand, places significant weight on the last indigenous Mesolithic populations capturing through their social networks essential information and Neolithic cultural

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elements (e.g. Rodríguez Alcalde et al. 1995; Vicent 1997). However the demic models suggested for the Western Mediterranean are neither monolithic nor exclusive; rather they tend to include the interaction between foreign and local populations to explain the observed neolithisation. For example the 'dual model' proposed for this process in the Mediterranean coast of Iberia implies the arrival—chiefly by sea—of Neolithic pioneers to certain coastal territories, their subsequent expansion and contact with the local Mesolithic population, involving possible frontier situations and consequently assimilation and/or acculturation processes (see Martí et al. 1987; Bernabeu and Martí 1992; Juan-Cabanilles 1992; Bernabeu 1997, 1999, 2002; Juan-Cabanilles and García Puchol 2013, among other works).

When we consider the 'identity' of the first Neolithic groups we refer to both the archaeological and the biological identity: perspectives from which there have been major developments in the study of neolithisation. In general the archaeological identity is inferred from stylistic analysis (e.g. Conkey and Hastorf 1993; Thomas 1996; Gamble 2007), identifying particular ways of making implements. For the case in question these analyses are focused on the chipped stone industries common in Neolithic and Mesolithic assemblages (see recent works on this specific topic in this territorial framework, Perrin 2006; García Puchol and Juan-Cabanilles 2012).

The biological identity is determined by genetic studies, most reliably of ancient DNA (see Fernández Domínguez et al. 2010) but also by other anthropological analyses that enable identification and differentiation of populations. Of particular note is the analysis of human teeth, involving their morphology (of the crown or dental root), measurements (crown) or geometric morphometry (molars), details which all hold important genetic relevance (see Ruiz and Subirà 2010). These kind of paleoanthropological studies are at the moment in an initial phase of development concerning the West Mediterranean area, particularly the dental analyses (see Ruiz et al. 2012), with as yet modest results (for studies on ancient DNA see Sampietro et al. 2007; Gamba et al. 2012, 2013; Lacan et al. 2014). Nonetheless studies of this kind, particularly of ancient DNA, clearly have much to offer in determining prehistoric identities.

In this chapter we make some reference to data provided by paleo-biological disciplines, in particular from ancient DNA (see the particular contribution in this book). But our main purpose is to focus on certain archaeological aspects of neolithisation, touching on identity from an archaeological perspective. Specifically, (1) we revise the population dynamics in the Western Mediterranean at the moment of the appearance of the Neolithic; (2) we check the coexistence and contact situations between Mesolithic and Neolithic populations, as contemplated in most of the demo-cultural models; and (3) we see how the stylistic analysis of chipped stone industries confirms the Mesolithic and Neolithic identities. We should point out that these themes have been considered in some recent meetings dedicated to the Neolithic transition in the Western Mediterranean (Perrin et al. 2013; Manen et al. 2014).

The spatial framework used as reference here is the Mediterranean coast of Iberia (Fig. 3.1), the Western end of the Mediterranean region, from which the available information (database and problems) can be contrasted with other Western Mediterranean territories: Southeast France and the Italian Peninsula.

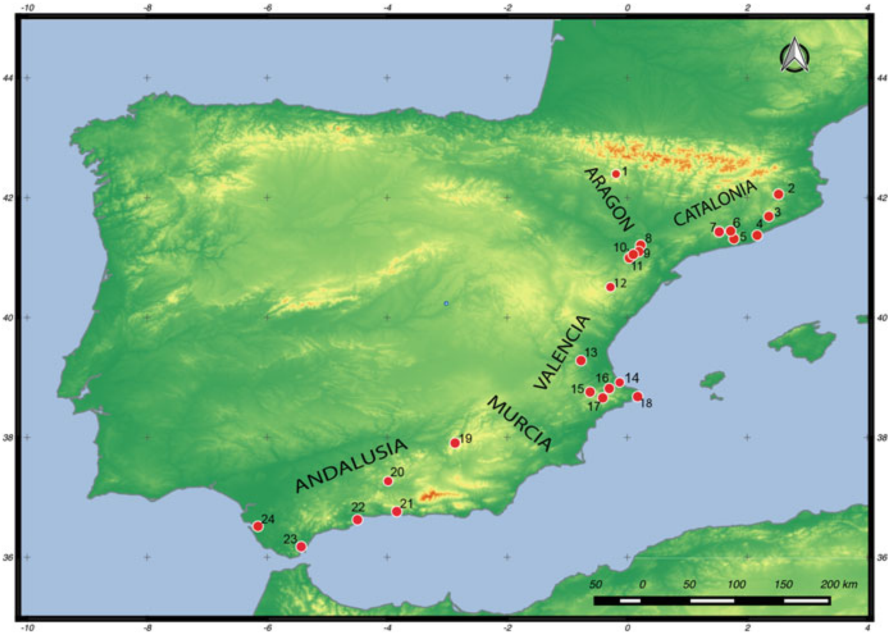

Fig. 3.1 Iberian Peninsula sites cited in the text: *1* Cueva de Chaves (Bastarás-Casbas, Huesca). *2* Cova de l'Avellaner (Cogolls-Les Planes d'Hostoles, Girona). *3* Camí de Can Grau (La Roca del Vallès, Barcelona). *4* Caserna de Sant Pau del Camp (Barcelona). *5* Cova de Can Sadurní (Begues, Barcelona). *6* Cova Bonica (Vallirana, Barcelona). *7* Les Guixeres (Vilobí, Barcelona). *8* Costalena (Maella, Zaragoza) *9* El Pontet (Maella, Zaragoza).*10* Els Secans (Mazaleón, Teruel). *11* Botiqueria dels Moros (Mazaleón, Teruel). *12*, Mas Cremat (Portell de Morella, Castellon). *13* Cueva de la Cocina (Dos Aguas, Valencia). *14* El Collao (Oliva, Valencia). *15* Cova de la Sarsa (Bocairent, Valencia). *16* Cova de l'Or (Beniarrés, Alicante). *17* Mas d'Is (Penàguila, Alicante). *18* Cova de les Cendres (Moraira-Teulada, Alicante). *19* Valdecuevas (Cazorla, Jaen). *20* Los Castillejos (Montefrío, Granada). *21* Cueva de Nerja (Nerja, Malaga). *22* Cueva Bajondillo (Torremolinos, Malaga). *23* Embarcadero del Río Palmones (Algeciras, Cadiz). *24* El Retamar (Puerto Real, Cadiz)

3.2 Mesolithic and Neolithic Settlement in the Northwest Mediterranean Region Between 6000 and 5000 cal BC

As it has been recently pointed out (Martí and Juan-Cabanilles 2014), the first Neolithic records on the Mediterranean coast of the Iberian peninsula appear at the middle of the 6th millennium cal BC, or shortly before, according to ^{14}C dates provided by Neolithic samples (cereal seeds or domestic sheep and goats). These evidences correspond to pastoral and agricultural groups established almost simultaneously at specific points along the coast from Catalonia to Andalusia (Fig. 3.2). That we are dealing with a 'Neolithic status' acquired over a number of generations is unmistakable, as the complete Neolithic 'package' (economic and technological)

Fig. 3.2 View of the Mediterranean coast from the area of Cova de les Cendres (from V. Villaverde)

is in evidence: domestic animals (sheep, goats, cattle, pigs, dogs), cereals (wheat, barley), pottery and polished stone axes. They live in open-air hamlets and caves; these last with other possible functions such as necropolis, livestock pens or religious/ritual spaces.

Initially, as we have mentioned, these groups of farmers and shepherds are located in some coastal areas, the low Llobregat basin in Catalonia, the territory between the Serpis and Gorgos rivers in the Valencia region and the littoral of Malaga in Andalusia. The pronounced distance between the first settlements and the short chronological gap between them reflect a rapid maritime spread of pioneers, linked with the first Neolithic of the Ligurian coast and the Tyrrhenian area, or maybe the Adriatic territories in Italy. This relationship can be deduced from the decorative style of the pottery, characterised by impressed techniques using a considerable variety of tools and objects. The 'impressed ware' culture in the Western Mediterranean includes several assemblages, of which the most distinctive and widespread is the 'cardial' pottery (present from the Adriatic to the Atlantic coast of Portugal), so called because of its decoration by impression using *cardium* shells (Fig. 3.3). The wide use of this technique explains the name 'cardial groups' applied to the first Neolithic groups of the Western Mediterranean, especially in Iberia, included in a particular 'culture': the 'Franco-Iberian Cardial' (see recent references: Guilaine 2007; Manen and Perrin 2009; Bernabeu et al. 2011).

Fig. 3.3 Cardium Pottery vessel of Cova de l'Or (archive Prehistory Museum of Valencia)

Currently, however, cardial ware is not conceived as a single cultural entity, while its traditional antiquity has been questioned due to other impressed ware recognised at first in southern France (Guilaine et al. 2007), and now in regions of Mediterranean Iberia: Valencia and Andalusia (Bernabeu et al. 2009; Soler et al. 2013; García Borja et al. 2014).

From those first Neolithic settlements in Mediterranean Iberia we observe a rapid expansion in all directions, along the coast and inland, sometimes reaching distant areas, as indicated by some sites situated in the Upper Ebro Valley and pre-Pyrenean mountains (see Martí 2008). This expansion, largely along river valleys, allows us to predict situations of contact with the last hunter-gatherer groups.

Nonetheless at the moment of the first Neolithic appearance in the Iberian Mediterranean territories there are few signs of the Mesolithic population (see Juan-Cabanilles and Martí 2002; García Puchol 2005; Fernández López de Pablo and Gómez Puche 2009). Areas which would be settled by these groups are sporadically distributed across the territory between the rivers Ebro and Júcar, and in addition possibly occasional sites in the Cazorla Mountains in the eastern interior of Andalusia. These groups can be associated with the latest manifestations of the 'Mesolithic Trapezes Complex', in particular with the 'Castelnovian' tradition recognised along the Western Mediterranean basin from the middle of the 7th millennium cal BC (Perrin et al. 2009; Perrin and Binder 2014). In the Iberian Mediterranean area the Castelnovian tradition is identified with the 'Cocina' facies of the Geometric Epipaleolithic or Late Mesolithic, established some years ago by

Fig. 3.4 Cueva de la Cocina, important site of the Late Mesolithic in the Mediterranean region of Iberia (from O. García Puchol)

Fortea (1973) from the record provided by the eponym site of 'Cueva de la Cocina' in the Valencia region (Fig. 3.4).

The Cocina facies, based on a new chrono-stratigraphical revision (García Puchol 2005; see also Juan-Cabanilles and Martí 2002; Martí et al. 2009), presents two main Late Mesolithic assemblages, characterised by specific geometric projectiles: a first phase where trapezes are dominant (phase A or Cocina I) developed mainly through the second half of the 7th millennium cal BC, and a second phase (phase B or Cocina II) with a predominance of characteristic triangular points ('Cocina-type triangles' with a lateral appendix) that would last through the first half of the 6th millennium cal BC.

The Mesolithic groups involved in phase B would witness the arrival of the first Neolithic populations. At this point in time (the middle of the 6th millennium cal BC) these local populations appear to inhabit a few specific areas in lower Aragon, and the north and centre of the Valencia region (see Fig. 3.5). Thus, the picture of the last Mesolithic settlement on the Iberian Mediterranean coast is marked by a substantial archaeological vacuum, which could indicate sporadic or continuous absences of population related to the cycles of economic mobility, a situation which cannot be realistically attributed to insufficient investigation. This vacuum covers the entire Catalonian territory (for specific information concerning this area see Vaquero and García-Argüelles 2009; Morales and Oms 2012; Morales et al. 2013), the southern area of Valencia, Murcia and most of Andalusia. In the case of Catalonia this

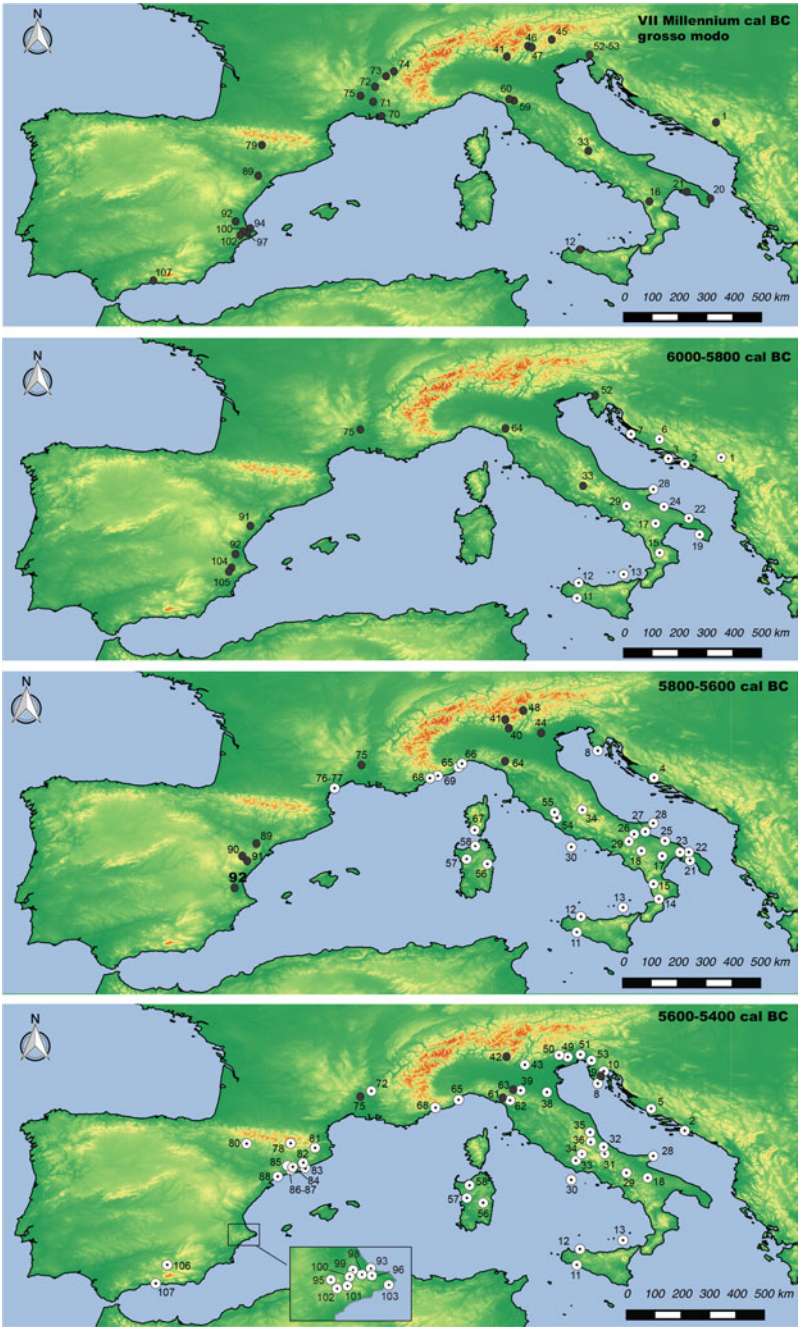

Fig. 3.5 Refer legend on next page

population lack also affects the trapeze phase (phase A), constituting nearly a thousand years without archaeological documentation. In Mediterranean Andalusia however we are beginning to detect some signs of late Mesolithic groups (phase A with trapezes) especially on the coast of Malaga (Nerja and Bajondillo caves; Aura et al. 2009; Cortés et al. 2012), whereas up to this point the clearest 'phase A' signs in Andalusia have been located in its Atlantic area, related to the Late Mesolithic of the South of Portugal (cf. the site of El Retamar; its difficulties in Zilhão 2011). However, despite the presence of phase A in Neolithic core areas such as the coast of Malaga and the south-central Valencia, there would still be a documentary/population vacuum of at least 400 years to bear in mind in any discussion.

Fig. 3.5 Main Mesolithic (*black dots*) and Neolithic (*white dots*) sites in the northwestern Mediterranean basin dated between 6900 and 5400 cal BC. Maps of the eastern Adriatic, Italy and south-east France based on Binder (2013), from dates with standard deviation lower than 100 and 1 sigma average calibration interval. For the Iberian Peninsula we have used the same criteria but only for dates on short-lived samples (except shells; see Table 3.1). Sites: *1* Odmut (Montenegro). *2* Gudnja (Bosnia-Herzegovina). *3* Grapceva (Croatia). *4* Skarin Samograd (Croatia). *5* Pokrovnik II (Croatia). *6* Gospodska (Croatia). *7* Tinj 1 (Croatia). *8* Vizula (Croatia). *9* Podosojna (Croatia). *10*, Pupi'cina (Croatia). *11* Stufe di San Calogero al Kronio (Agrigento). *12* Grotta de l'Uzzo (Trapani). *13* Lipari (Messina). *14* Piana di Curinga (Catanzaro). *15* Favella della Corte (Cosenza). *16* Grotta Latronico 3 (Potenza). *17* Rendina (Potenza). *18* Trasano 1 (Matera). *19* Torre Sabea (Lecce). *20* Grotta Marisa (Lecce). *21* Terragne (Tarento). *22* Grotta San Angelo (Brindisi). *23* Torre Cane (Brindisi). *24* Pulo di Molfetta (Bari). *25* Scamuso (Bari). *26* Rippa Tetta (Foggia). *27* Coppa Nevigata (Foggia). *28* Defensola (Foggia). *29* La Starza (Avellino). *30* Palmarolla (Ponza Latina). *31* Fonti Rossi (Chieti). *32* Marcianese (Chieti). *33* Grotta Continenza (L'Aquila). *34* Colle San Stefano (L'Aquila). *35* Catignano (Pescara). *36* Villaggio Leopardi (Pescara). *37* Maddalena di Mucia (Macerata). *38* Lugo di Romagna (Ravenna). *39* Fiorano Modenese (Modena). *40* Fienile-Rossino (Brescia). *41* Laghetti del Crestoso (Brescia). *42* Stanga di Bassinale (Brescia). *43* Lugo di Grezzana (Verona). *44* Covoloni del Broion (Vicenza). *45* Mondeval de Sora (Belluno). *46* Romagnano III (Trento). *47* Vatte di Zambana (Trento). *48* Pradestel (Trento). *49* Fagnigola (Pordenone). *50* Valer (Pordenone). *51* Sammardenchia (Udine). *52* Benussi (Trieste). *53* Edera (Trieste). *54* La Marmotta (Rome). *55* Monte Venere (Viterbo). *56* Corbeddu (Nùoro). *57* Filiestru (Sassari). *58*, Su Coloru (Sassari). *59* Piazzana (Lucca). *60* Isola Santa (Lucca). *61* Monte Frignone (Lucca). *62* Pian di Cerreto (Lucca). *63* Lama Lite II (Reggio Emilia). *64* Passo della Comunella (Reggio Emilia). *65* Arene Candide (Savona). *66* San Sebastiano di Perti (Savona). *67* Renaghju (Corse-du-Sud). *68*, Pendimoun (Alpes-Maritimes). *69* Caucade (Alpes-Maritimes). *70* Font-des-Pigeons (Bouches-du-Rhône). *71* Mourre du Sève (Vaucluse). *72*, Lalo (Drôme). *73* Pas de la Charmatte (Isère). *74* Grand Rivoire (Isère). *75* Baume de Montclus (Gard). *76* Pont-de-Roque-Haute (Hérault). *77* Peyrosignado (Hérault). *78* Balma de la Margineda (Andorra). *79* Forcas II (Huesca). *80* Cueva de Chaves (Huesca). *81* Balma del Serrat del Pont (Girona). *82* Cova del Toll (Barcelona). *83* Plaça Vila de Madrid (Barcelona). *84* Can Sadurní (Barcelona). *85* Les Guixeres (Barcelona). *86* Vinya d'en Pau (Barcelona). *87* La Serreta (Barcelona). *88* El Cavet (Tarragona). *89* Botiqueria dels Moros (Teruel). *90* Mas Cremat (Castellon). *91* Mas Nou (Castellon). *92* Cueva de la Cocina (Valencia). *93* El Barranquet (Valencia). *94* El Collao (Valencia). *95* Cova de la Sarsa (Valencia). *96* Cova Fosca (Alicante). *97* Tossal de la Roca (Alicante). *98* Cova d'en Pardo (Alicante). *99* Cova de l'Or (Alicante). *100* Benàmer (Alicante). *101* Mas d'Is (Alicante). *102* Falguera (Alicante). *103* Cova de les Cendres (Alicante). *104* Casa Corona (Alicante). *105* Cueva del Lagrimal (Alicante). *106* Cueva de la Carigüela (Granada). *107* Cueva de Nerja (Malaga)

Table 3.1 More reliable dates from short-lived samples of the Mesolithic/Neolithic sites in the Mediterranean Iberia (6990–5400 cal BC)

Site and level	Lab. #	Material	^{14}C BP Date	1σ Cal BC (OxCal)	Cultural period	Reference
Catalonia						
Guixeres A	OxA-26068	*Ovis aries*	6655 ± 45	5626–5551 (68.2%)	Neo	Oms et al. (2014)
Guixeres A	OxA-26069	*Ovis aries*	6458 ± 38	5476–5462 (11.6%) 5448–5378 (56.6%)	Neo	Oms et al. (2014)
Margineda 3b	Not id.	*Corylus avellana*	6410 ± 40	5467–5401 (45.4%) 5390–5356 (22.8%)	Neo	Oms (2014)
Cavet UE2012	OxA-26,061	*Triticum aestivum/ durum*	6536 ± 36	5522–5476 (68.2%)	Neo	Oms (2014)
Cavet UE2014	OxA-25802	*Triticum aestivum/ durum*	6440 ± 40	5471–5460 (8.5%) 5451–5376 (59.7%)	Neo	(Oms 2014)
Serreta E61	Beta-280,862	*Arbutus unedo*	6490 ± 40	5488–5463 (26.6%) 5446–5418 (18.2%) 5410–5380 (23.4%)	Neo	Oms (2014)
Serreta E79	Beta-280866	*Arbutus unedo*	6420 ± 40	5468–5399 (50.2%) 5392–5367 (18.0%)	Neo	Oms (2014)
Serreta E59	Beta-280,860	Angiosperm	6410 ± 40	5467–5401 (45.4%) 5390–5356 (22.8%)	Neo	Oms (2014)
Serrat del Pont III.4	Beta-172521	*Sus scropha*	6470 ± 40	5480–5462 (16.0%) 5447–5379 (52.2%)	Neo	Oms (2014)
Plaça Vila Madrid	Beta-18,271	Human bone	6440 ± 40	5471–5460 (8.5%) 5451–5376 (59.7%)	Neo	Oms (2014)
Cova del Toll 2b	OxA-26070	*Ovis aries*	6425 ± 35	5467–5400 (52.8%) 5391–5371 (15.4%)	Neo	Oms (2014)
Can Sadurní C18	OxA-15,488	*Triticum dicoccum*	6421 ± 34	5467–5401 (52.2%) 5390–5369 (16.0%)	Neo	Oms (2014)

(continued)

Table 3.1 (continued)

Site and level	Lab. #	Material	^{14}C BP Date	1σ Cal BC (OxCal)	Cultural period	Reference
Can Sadurní C18	UBAR-760	Seeds (undeterm.)	6405 ± 50	5466–5404 (38.1%) 5386–5340 (30.1%)	Neo	Oms (2014)
Vinya d'en Pau E1	CNA-2488.1.1	*Ovis aries*	6410 ± 40	5467–5401 (45.4%) 5390–5356 (22.8%)	Neo	Oms (2014)
Aragon						
Botiqueria 2	GrA-13265	*Cervus elaphus*	7600 ± 50	6482–6416 (68.2%)	Meso	Barandiarán and Cava (2002)
Botiqueria 4	GrA-13267	Faunal bone (unspecified)	6830 ± 50	5748–5661 (68.2)	Meso	Barandiarán and Cava (2002)
Forcas-II II	Beta-250944	Faunal bone (unspecified)	7150 ± 40	6054–5998 (68.2%)	Meso	Utrilla et al. (2009)
Chaves Ib	GrA-38022	*Ovis aries*	6580 ± 35	5552–5486 (68.2%)	Neo	Baldellou (2011)
Chaves Ib	UCI-AMS-66317	*Ovis aries*	6470 ± 25	5479–5382 (68.2%)	Neo	Baldellou (2011)
Valencia Region						
Collao burial 9	CNA-1625.1.1	Human bone	7801 ± 38	6659–6594 (68.2%)	Meso	Gibaja et al. (2015)
Collao burial 11	CNA-1626.1.1	Human bone	7742 ± 35	6611–6557 (39.1%) 6551–6507 (29.1%)	Meso	Gibaja et al. (2015)
Tossal de la Roca I	Gif-6898	Faunal bones (unspecified)	7660 ± 80	6588–6578 (4.5%) 6574–6449 (63.7%)	Meso	Martí et al. (2009)
Tossal de la Roca I	Gif-6897	Faunal bones (unspecified)	7560 ± 80	6491–6355 (62.1%) 6292–6268 (6.1%)	Meso	Martí et al. (2009)
Cocina I (c.17)	Beta-267440	*Capra pyrenaica*	7610 ± 40	6478–6431 (68.2)	Meso	Juan-Cabanilles and García Puchol (2013)

Cocina I (c.12)	Beta-267438	*Capra pyrenaica*	7350 ± 40	6326–6320 (2.2%) 6252–6203 (34.1%) 6192–6182 (3.9%) 6172–6156 (6.0%) 6146–6101 (21.9%)	Meso	Juan-Cabanilles and García Puchol (2013)
Cocina II (c.8)	Beta-267436	*Capra pyrenaica*	7080 ± 50	6012–5968 (32.5%) 5956–5906 (35.7%)	Meso	Juan-Cabanilles and García Puchol (2013)
Cocina II (c.10)	Beta-267437	*Capra pyrenaica*	7050 ± 50	5991–5892 (68.2%)	Meso	Juan-Cabanilles and García Puchol (2013)
Cocina II (c.6)	Beta-267435	*Capra pyrenaica*	6840 ± 50	5759–5665 (68.2%)	Meso	Juan-Cabanilles and García Puchol (2013)
Cocina II (c.13)	Beta-267439	*Capra pyrenaica*	6760 ± 40	5706–5634 (68.2%)	Meso	Juan-Cabanilles and García Puchol (2013)
Falguera VIII	AA-59519	Pinecone	7526 ± 44	6446–6372 (68.2%)	Meso	García Puchol and Aura (2006
Falguera (without ref.)	AA-2295	*Olea* seed	7410 ± 70	6378–6227 (68.2%)	Meso	García Puchol and Aura (2006)
Falguera VII	Beta-267441	*Cervus elaphus*	7380 ± 40	6356–6291 (32.7%) 6269–6216 (35.5%)	Meso	García Puchol and Aura (2006)
Falguera VI	I-10463	*Triticum monococcum*	6510 ± 80	5538–5460 (38.1%) 5451–5376 (30.1%)	Neo	García Puchol and Aura (2006)
Benàmer I	CNA-680	Pollen	7490 ± 50	6427–6352 (48.0%) 6308–6265 (20.2%)	Meso	Torregrosa et al. (2011)
Benàmer I	Beta-287331	Arbutus unedo	7480 ± 40	6416–6351 (43.6%) 6308–6264 (24.6%)	Meso	Torregrosa et al. (2011)
Benàmer II	CNA-539	Pollen	6575 ± 50	5602–5599 (1.9%) 5558–5482 (66.3%)	Neo	Torregrosa et al. (2011)
Casa Corona burial 2	OxA-V-2392-92	Human bone	7116 ± 32	6026–5982 (60.8%) 5940–5930 (7.4%)	Meso	Fernández López de Pablo et al. (2012)
Casa Corona burial 1	Beta-272856	Human bone	7070 ± 40	6002–5970 (27.5%) 5954–5910 (40.7%)	Meso	Fernández López de Pablo et al. (2012)

(continued)

Table 3.1 (continued)

Site and level	Lab. #	Material	^{14}C BP Date	1σ Cal BC (OxCal)	Cultural period	Reference
Mas Nou 3	Beta-170714	Human bone	7010 ± 40	5978–5946 (22.3%) 5922–5871 (36.2%) 5862–5846 (9.7%)	Meso	Salazar-García et al. (2014)
Mas Nou 3	OxA-V-2360-29	Human bone	6925 ± 35	5839–5751 (68.2%)	Meso	Salazar-García et al. (2014)
Mas Nou 3	Beta-170715	Human bone	6920 ± 40	5838–5746 (68.2%)	Meso	Salazar-García et al. (2014)
Mas Nou 3	OxA-V-2360-28	Human bone	6897 ± 34	5807–5731 (68.2%)	Meso	Salazar-García et al. (2014)
Lagrimal IV	Beta-249,933	*Capra pyrenaica*	6990 ± 50	5976–5811 (68.2%)	Meso	Fernández-López de Pablo et al. (2012)
Mas Cremat V	Beta-232341	*Corylus* seed	6800 ± 50	5726–5656 (68.2%)	Meso	Vicente (2010)
Mas Cremat VI	Beta-232342	*Corylus* seed	6780 ± 50	5714–5644 (68.2%)	Meso	Vicente (2010)
En Pardo VIII	Beta-231879	*Ovis*/*Capra*	6610 ± 40	5614–5587 (21.9%) 5568–5514 (46.3%)	Neo	Soler et al. (2013)
Mas d'Is UE80224	Beta-239378	Monocotile-donean plant	6600 ± 40	5610–5591 (14.5%) 5564–5508 (47.8%)	Neo	Bernabeu et al. (2009)
Mas d'Is UE80205	Beta-166727	*Hordeum vulgare*	6600 ± 50	5610–5590 (14.2%) 5564–5491 (54.0%)	Neo	Bernabeu et al. (2009)
Mas d'Is UE80209	Beta-162,092	*Hordeum vulgare*	6600 ± 50	5610–5590 (14.2%) 5564–5491 (54.0%)	Neo	Bernabeu et al. (2009)
Cendres H19	Beta-239377	*Ovis aries*	6510 ± 40	5526–5386 (68.2%)	Neo	Bernabeu et al. (2009)
Cendres H16	GifA-101360	*Triticum dicoccum*	6490 ± 90	5530–5365 (68.2%)	Neo	Bernabeu et al. (2009)
Barranquet UE79	Beta-221431	*Ovis aries*	6510 ± 50	5530–5465 (49.1%) 5440–5424 (7.2%) 5406–5384 (11.9%)	Neo	Bernabeu et al. (2009)
Sarsa	OxA-V-26076	*Ovis aries*	6506 ± 32	5516–5466 (59.7%) 5402–5388 (8.5%)	Neo	García Borja et al. (2012a)

Sarsa	OxA-V-26075	*Ovis aries*	6420 ± 32	5467–5402 (52.1%) 5389–5368 (16.1%)	Neo	García Borja et al. (2012a)
Or VI	UCI-AMS-66316	*Ovis aries*	6475 ± 25	5480–5464 (24.6%) 5441–5423 (15.9%) 5406–5383 (27.7%)	Neo	Juan-Cabanilles and García Puchol (2013)
Fosca Ebo	OxA-26047	*Ovis aries*	6413 ± 33	5467–5402 (48.1%) 5390–5362 (20.1%)	Neo	García Borja et al. (2012b)
Andalusia						
Nerja V3c	GifA-102010	*Pinus pinea* seed	7610 ± 90	6587–6582 (1.4%) 6570–6541 (9.2%) 6534–6396 (57.6%)	Meso	Aura et al. (2013)
Nerja M11	Beta-284148	*Pinus pinea* seed	7490 ± 40	6426–6354 (54.1%) 6293–6267 (14.1%)	Meso	Aura et al. (2013)
Nerja M11	Beta-284146	*Lathyrus* sp. seed	7150 ± 40	6054–5998 (68.2%)	Meso	Aura et al. (2013)
Nerja V3 (fosa)	Beta-131577	*Ovis aries*	6590 ± 40	5603–5597 (4.6%) 5559–5490 (63.6%)	Neo	Aura et al. (2013)
Nerja M12	OxA-26086	*Ovis/Capra*	6466 ± 33	5478–5464 (15.8%) 5445–5420 (22.7%) 5410–5380 (29.7%)	Neo	Aura et al. (2013)
Carigüela XV	Col-1566.1.1	Sheep/goat	6482 ± 39	5484–5463 (22.4%) 5446–5418 (20.1%) 5410–5380 (25.7%)	Neo	Medved (2013)

Calibrated with OxCal v 4.2.3 Bronk Ramsey (2009); r:5 and IntCal13 atmospheric curve (Reimer et al. 2013)

Based on the available information on Mesolithic settlement in the Mediterranean area of Iberia, we can therefore conclude that the first Neolithic 'pioneers' occupy empty or sparsely inhabited areas, as has been observed in other parts of the Western Mediterranean (Fig. 3.5). As indicated by a recent cartography of the neolithisation of this region (Binder 2013), the area of the first documented Neolithic settlement (Impressed-Cardial Complex), in Southern Italy (Apulia, Calabria, Sicily, Campania), reveals no clear evidences of Castelnovian Mesolithic sites between 6000 and 5800 cal BC (see also Grifoni Cremonesi and Radi 2014), although these can be found in other Italian territories in the centre (Abruzzo) and north (Apenino Tosco-Emilia and Friuli). During the period 5800–5600 cal BC in the southeast of France we can only point to one Castelnovian site, Baume de Montclus in the middle-lower Rhône basin. The first Neolithic settlements in this area, also linked with the Impressed-Cardial Complex (*Impressa* cultural horizon), are located on the coast of Languedoc and eastern Provence, this latter area having its population/cultural continuity in the Italian Liguria, neither of which reveal a Mesolithic population in this period (see Binder 2013, Perrin 2013).

3.3 Testing Neolithic/Mesolithic Contact and Interaction

It need to scarcely be said that any contact between populations requires a prior coexistence, which in the case in hand needs to be demonstrated. There are two principal ways to prove contemporary situations in recent prehistory, such as the Neolithic/Mesolithic: chronology—assessing overlapping between dates (particularly radiocarbon dates), and from stratigraphic data relating to archaeological sequences (investigating situations of possibly interrelated strata: Mesolithic between Neolithic occupations or vice versa).

In Mediterranean Iberia there are a few archaeological sequences with levels related to the last Mesolithic groups (Cocina facies, phase B) and the first Neolithic: namely Botiqueria dels Moros and Costalena in Lower Aragon region; Mas Cremat in the north of the Valencia region; and Cueva de la Cocina in the central Valencia region (see Juan-Cabanilles and García Puchol 2013). The problem is that, in all cases, the Mesolithic and Neolithic levels appear in continued or discontinued sequence, but never Mesolithic between Neolithic occupations, which precludes any verification of contemporaneity, however close in time the ^{14}C dates of these levels may be, although this rarely occurs. We have to turn to absolute chronology, but from a different perspective; and we need to select the most reliable dates, those that provide specific short-life samples and clear anthropic evidence (cereal grains, bones of domestic sheep and goats, human bones, wild animal bones with evidence of human consumption, bone ornaments; even well-identified and contextualised charcoal). An increasing proportion of investigators recognise this need for scrupulous sample selection (see Zilhão 2001, 2011; Binder 2005, 2013; Bernabeu 2006; Martí et al. 2009; Manen 2014), especially when the debate revolves around origins, relative antiquity, etc. of prehistoric cultural processes.

Bearing this in mind, the most ancient dates available for the Neolithic in the Iberian Mediterranean region come from these sites (see Table 3.1):

- Les Guixeres (Horizon A), in the Neolithic Catalan nucleus: 6655±45 BP (Oxa-26068) from a bone of *Ovis aries* (Oms et al. 2014). Cal BC 1 σ: 5626–5551 (68.2%); Cal BC 2 σ: 5644–5491 (95.4%). This and the remaining dates have been calibrated using OxCal 4.2 software (Bronk Ramsey 2009), IntCal 13 curve (Reimer et al. 2013).
- Mas d'Is (UE80219), in the Valencian nucleus: 6600±50 BP (Beta-162092), from a *Hordeum* seed (Bernabeu 2006). Cal BC 1 σ: 5610–5590 (14.2%), 5564–5491 (54.0%); cal BC 2 σ: 5621–5481 (95.4%).
- Cueva de Nerja (NV-3, pit), in the Andalusian nucleus of the coast of Málaga: 6590±40 BP (Beta-131577), from a bone of *Ovis aries* (Aura et al. 2009). Cal BC 1 σ: 5603–5597 (4.6%), 5559–5490 (63.6%); cal BC 2 σ: 5616–5581 (19.7%), 5575–5480 (75.7%).

The most recent radiocarbon dates for the Mesolithic in the same area, related to the phase B, proceed from:

- Botiqueria dels Moros (level 4), in the low Aragon Mesolithic nucleus (middle-lower basin of Ebro river): 6830±50 BP (GrA-13267), from an unspecified animal bone (Barandiarán and Cava 2002). Cal BC 1 σ: 5748–5661 (68.2%); cal BC 2 σ: 5834–5826 (0.9%), 5812–5633 (94.5%).
- Mas Cremat (level VI), in the High Maestrazgo nucleus (northern interior of Valencia region): 6780±50 BP (Beta-232342), from a *Corylus* seed (Vicente 2010). Cal BC 1 σ: 5714–5644 (68.2%); cal BC 2 σ: 5752–5616 (95.4%).
- Cueva de la Cocina (layer 13), in the middle Júcar valley nucleus (central interior Valencian region): 6760±40 BP (Beta-267438), from a bone of *Capra pyrenaica* (Juan-Cabanilles and García Puchol 2013). Cal BC 1 σ: 5706–5684 (20.4%), 5676–5634 (47.8%); cal BC 2 σ: 5726–5621 (95.4%). Based on the layer where the sample was found it should be affiliated to the Cocina I level (=phase A, dated in this site between 6565 and 6080 cal BC 2 σ); however there is no doubt that these sample dates Cocina II level (= phase B, also dated here from other samples between 6052 and 5639 cal BC 2 σ; cf. Table 3.1). This is a bone fragment clearly displaced from its original location, with signs of butchery which reveal its anthropogenic handling.

As we can see the date of the Catalan Neolithic site of Les Guixeres overlaps with the latest nearest Mesolithic site, the rockshelter of Botiqueria dels Moros in Low Aragon (at a direct distance of 150 km) by 11 years (2 sigma)—using the highest calibration value in the first case and the lowest in the second. There is also an overlap of 28 years (2 sigma) with the rockshelter of Mas Cremat (close to 200 km as the crow flies) (Fig. 3.6). The site of Mas d'Is in the Valencian Neolithic nucleus is situated about 70 km from the nearest Mesolithic site of Cueva de la Cocina; and their dates overlap only in 0–1 years (2 sigma) (Fig. 3.6).

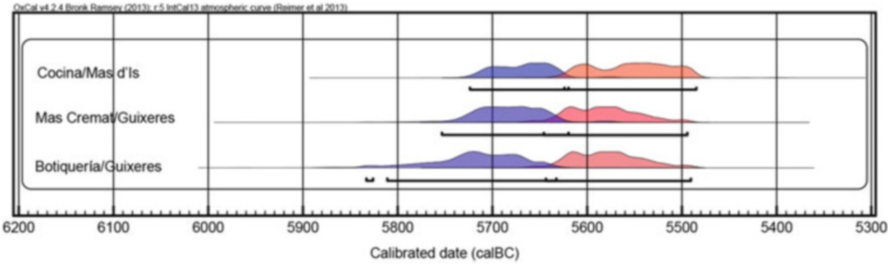

Fig. 3.6 Mesolithic and Neolithic overlapping plots from calibrated 2 sigma range dates

There are no phase B Mesolithic sites near to the Andalusian site of Cueva de Nerja. The closest would be the Río Palmones site in the Algeciras bay (at 150 km), if its relation with this phase is finally confirmed (Ramos and Castañeda Coord. 2005). Other sites such as Valdecuevas, in the mountainous interior of Eastern Andalusia ('sierra' of Cazorla) hold certain possibilities of belonging to phase B, but this has no radiocarbon dates and is situated more than 180 km from Nerja.

Considering all these sites based on the 2 sigma radiocarbon calibration dates (there is no overlapping at 1 sigma), the coexistence between Mesolithic and Neolithic groups in their respective territories could possibly have occurred during a minimum interval of 0–1 years (data from Nerja compared with Mas Cremat) and a maximum of 28 (data from Les Guixeres compared also with Mas Cremat). Obviously this is a very forced and limited 'contemporaneity' that requires more radiocarbon dates, especially for the Mesolithic, to permit a more solid conclusion. For the time being coexistence between Mesolithic and Neolithic groups can only be observed over a wider spatial framework, extending from the Mediterranean to include inner areas such as the Upper Ebro territories, some Pyrenean areas and the Cantabrian coast; but even so the lack of good radiocarbon date series from the more recent Mesolithic continues to be a hindrance (Utrilla and Montes 2009).

If we move to the South of France, a recent work has addressed Mesolithic/Neolithic contact from a similar perspective, evaluating absolute chronology and geographical distribution (Perrin 2013). While keeping in mind that some of the radiocarbon dates do not correspond to short-life samples, contact could have taken place after 5850 cal BC, when we have the first evidence of Neolithic presence in the coastal zone. The most reliable possibility is offered by the Grotte de Montclus, located in the middle Rhône valley, where the Mesolithic presence appears to reach 5600 cal BC. By that time the early Neolithic would be present on the western shores of Languedoc and Provence (left bank of the Rhône), at a distance of 110 km in each case. In Montclus itself, however, the first Neolithic does not arrive for another 200 years. Further upstream along the Rhône, in the upper-middle basin, the last Mesolithic levels of the Grande-Rivoire site are dated towards 5400 cal BC, at a distance of 80 km from Neolithic sites, although again, the first Neolithic is seen at Grande-Rivoire itself 250 years later. Continuing northwards up the Rhône basin the Grotte du Gardon in southern Jura could offer the best example of coexistence between Mesolithic and Neolithic peoples, if the intercalation of a Mesolithic level between Neolithic levels at the beginning of the long sequence here is conclusively confirmed (see Perrin 2003, confronted with Voruz et al. 2004).

Possibilities of contact in the Italian Peninsula have also been analysed by the same method (Perrin and Binder 2014), although current data are not of sufficient quality to constitute proof. In southern Italy the current radiocarbon dates for the latest Castelnovian Mesolithic levels and the most recent for the *Impressa* facies of the Early Neolithic, all taken from long-life samples (charcoal) and with large standard deviations, do not demonstrate coexistence between the two entities. However to the north of the peninsula, especially in the Tuscan Apennines, dates and distances between sites plausibly suggest coexistence or even contact towards the end of the Castelnovian phase (shortly before the mid-6th millennium cal BC).

It becomes evident that in most areas of Western Mediterranean Europe there is a lack of conclusive data to corroborate a coexistence between Mesolithic and Neolithic groups. Nonetheless it would be illogical to doubt the existence of Mesolithic populations at the moment of the first Neolithic arrivals: and equally it is logical to suppose that this contemporaneity would result sooner or later in contact and cultural interaction, depending on the direction and speed of the Neolithic spread.

In Mediterranean Iberia, some studies have sought to offer evidence of this contact by identifying a third Mesolithic Cocina phase, termed C and also defined time ago by Fortea (1973) from level III of this site. The complementary information offered by several sites located in the lower Aragon region (particularly the rockshelters of Costalena, Pontet and Secans; see Utrilla et al. 2009) suggests for this phase a collection of Mesolithic industrial traditions, most of them present in the previous B phase (triangular geometric Cocina-type projectiles, crescents, backed bladelets, etc.), alongside certain Neolithic elements, mainly ancient pottery styles (cardial, epicardial), and a particular retouch technique (bifacial) used for making certain geometric projectiles (triangles and crescents) named *doble bisel* (see Juan-Cabanilles and Martí 2007–2008). None of the sites or levels traditionally linked with this Mesolithic phase C reveal economic Neolithic evidences (crops or domestic animals), so that this initial Mesolithic neolithisation would appear to be a simple technological transfer.

Recently the real identity of this phase C has been questioned, above all at the eponym Cocina site where it arose, due to a new revision of the excavation sectors studied by Fortea, and the resultant conclusions on stratigraphy and material associations (García Puchol 2005). This revision, based on the recorded fieldwork from the 1940s (conducted by L. Pericot) and the techno-typological analysis of lithic and pottery remains, reveals that the upper section of the sequence where level III is located presents serious taphonomic problems due to strong post-depositional disturbances that would have caused a mixing of Neolithic, Chalcolithic and more modern materials with Mesolithic remains. Consequently phase C could not be identified at the site, at least with the currently available information.

Phase C presents additional problems to those detected in Cocina (see Juan-Cabanilles and García Puchol 2013), and conclusions based on the readings of available data are to a certain extent subjective. A relatively recent work looked at alternative possibilities (Juan-Cabanilles and Martí 2007–2008): in contrast to the classic view, seeing a first Mesolithic/Neolithic contact materialised in technological transfers, phase C could be the expression of functional states within the Early Neolithic. This idea is based on the presence of Neolithic technological features in the assemblages attributed to this phase, without domestic economic evidences. Nevertheless that would require us to explain the existence in these assemblages of some Mesolithic technological components. This leads us to an alternative interpretation based on the idea that an initial neolithisation of the Mesolithic would leave little or no footprint in the stratigraphic record. Consequently, as suggested for Cocina, phase C would be simply a mixed horizon due to the confusion of some materials from Mesolithic phase B and others from the Early Neolithic. The formation of such archaeological contexts could result from Neolithic occupations (probably of a functional nature) of places settled previously by Mesolithic groups.

Despite these misgivings a 'phase C', resulting from Mesolithic/Neolithic contact, remains a proposal consistent with the idea of the persistence, expansion and interaction processes linked with neolithisation. Recognising the contact or interactions becomes a fundamental issue, a task made feasible by the identification of expected technological transfers. The problem resides in determining which transfers have occurred and in which directions. Going back to the bifacial retouch (*doble bisel*) technique mentioned above, originally considered to be Neolithic (1970s): it then became a Mesolithic technique (1980s), and later returned to the Neolithic (2000+) (see Juan-Cabanilles 2008: 248–249). To resolve this and similar questions (who lent what to whom and when) there is a general need of better stratigraphic sequences and better radiocarbon dates. In other words, current data about the possibility of technological transfer have not as yet attained satisfactory standards of reliability in taphonomy and chronology: a conclusion extensible to the rest of the West European Mediterranean.

3.4 Confirming Mesolithic and Neolithic Identities

The identity referred to here is, as previously explained, the archaeological identity, determinable in principle from the comparative analysis between Neolithic and Mesolithic lithic industries. These assemblages are in general well known in different areas of the northwest Mediterranean basin, although their study has only on a few occasions been conducted applying explicit criteria of style, such as the 'isochrestic' method (proposed by Sackett 1982, 1986) or the 'reductionist' method (Close 1978, 1989). In this work we try to address lithic aspects and features—technological and morphological—with the highest possible indication of style, rather than to describe the general qualitative or quantitative characteristics. We view style in an eclectic manner, that is, as distinctive arrangements of material attributes resultant from certain ways of doing, being also a consequence of cultural selections between two or more different but functionally equivalent options (Juan-Cabanilles 2008: 11–15).

Focusing on Mediterranean Iberia, well-defined or confirmed stylistic differences between Recent Mesolithic and Early Neolithic are few, but their relevance is quite significant. Starting with the supply of raw materials for knapping, although probably not the easiest aspect to consider, the Valencian Cardial Neolithic—for example—seems to employ a greater diversity of siliceous rock types than the Cocina Mesolithic facies, adding to the local high-quality flint varieties jasper (probably imported), and crystal quartz (García Puchol 2005). Both varieties appear in low percentages in the Cardial assemblages, but are unknown in Mesolithic contexts. Jasper however appears profusely in some Catalan Cardial sites, particularly in the Barcelona plain (Borrell and Molist 2012), a fact explained by their proximity to primary sources (the Montjuïc mountain); nonetheless the total lack of information about Catalonian Mesolithic groups prevents any evaluation. A greater stylistic relevance could be seen in the preferential use of 'blonde' flint by Cardial Neolithic groups in Vaucluse in French Provence, in comparison with the more varied choice of silex (including blonde) in the Mesolithic lithic assemblages of the same region (Binder 1998). Each would have had the same access to raw materials for knapping industries based on similar blade technology, within a fairly brief time framework.

In relation with blade technology, that is, the making of elongated and thin supports (blades and bladelets) from carefully prepared cores, the Valencian Cardial Neolithic uses a surrounding or semi-surrounding removal system that produces blades with a marked typometric variation (García Puchol and Juan-Cabanilles 2012) (Fig. 3.7). A similar semi-surrounding pattern has been indicated in some Catalan Cardial assemblages (Borrell and Molist 2012). On the other hand, Cocina Mesolithic facies (phases A and B) present a frontal extraction that produces blades and bladelets which are metrically more uniform (García Puchol and Juan-Cabanilles 2012) (Fig. 3.8). Both systems, Neolithic and Mesolithic, indicate the use of pressure and indirect percussion techniques, depending on the phase of core reduction. A distinctive feature however is the use of heat to improve the knapping process: a procedure linked with the use of pressure techniques which is unknown in Mesolithic contexts, but well identified in the Catalan Cardial context (Borrell and Molist 2012) and the Andalusian Early Neolithic (data from Cueva de Nerja—Aura et al. 2013, and Los Castillejos—Sánchez Romero 2000; Martínez Fernández et al. 2010). Although evidence is not yet conclusive, this system also seems probable in the Valencian Cardial.

From a technological point of view we can also consider a specific procedure for splitting blades. In the Cocina Mesolithic facies, particularly in the later B phase, the microburin technique is very common in relation with the production of geometric tools. But this technique is not present in the Valencian Cardial and other Early Neolithic groups in Mediterranean Iberia, where the 'flexion' procedure is used (Juan-Cabanilles 2008: 14, 217, 245). The same seems to be the case in the Provençal Cardial and the Italian Tyrrenian Cardial (Binder 1987: 172; Manen and

Fig. 3.7 Early Neolithic cores and blades from Cova de l'Or (Valencia Region)

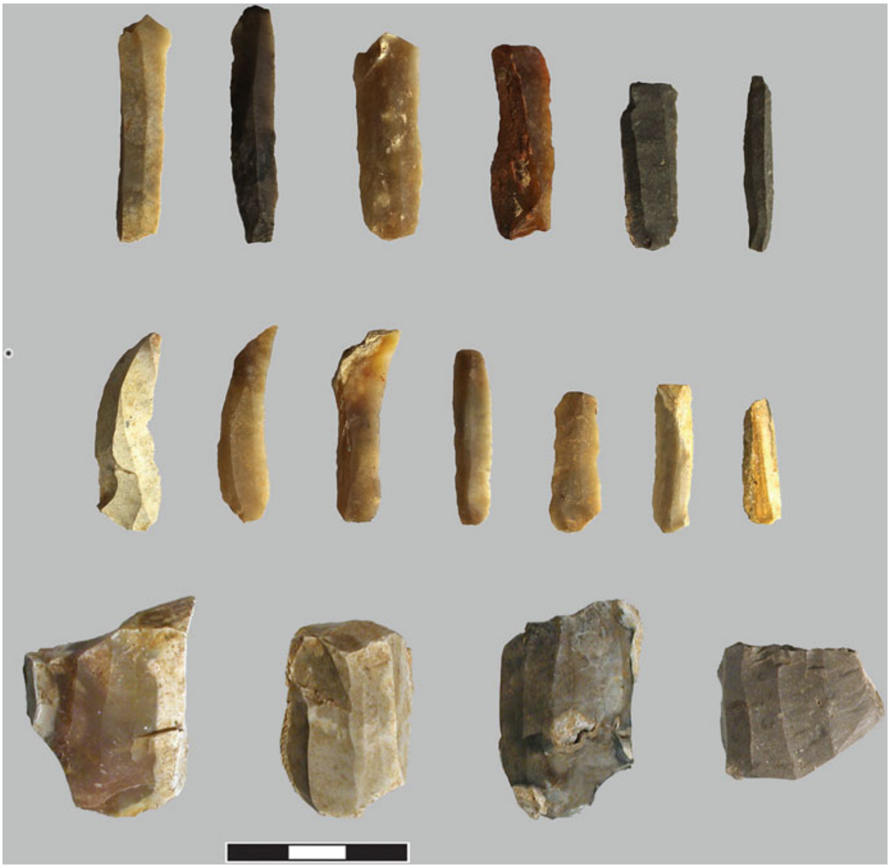

Fig. 3.8 Late Mesolithic (Phase B) cores and bladelets from Cueva de la Cocina (Valencia Region)

Perrin 2009: 435), whereas the microburin technique is widely documented in the Castelnovian Mesolithic.

From a typological or morphological perspective, stylistic features frequently arise more clearly, especially when we analyse functional tools which have required greater modification, that is, with strong technical investment. Hunting tools present special possibilities in this sense. For example, the latest Mesolithic geometric projectiles in Mediterranean Iberia, characteristic of phase B, are represented by Cocina-type triangles. These pieces consist of small triangular shapes with concave sides, retouched directly and abruptly, with a marked appendix (Fortea 1973: 99). This singularity, also present in the last Portuguese Mesolithic (Muge-type triangles), contrasts with the main geometric projectiles documented in the Early Neolithic assemblages, where trapezes showing straight or concave sides and abrupt or semi-abrupt retouch are characteristic, sometimes with a flat retouch as opposed to an abrupt retouch (Juan-Cabanilles 2008) (Fig. 3.9). Depending on the

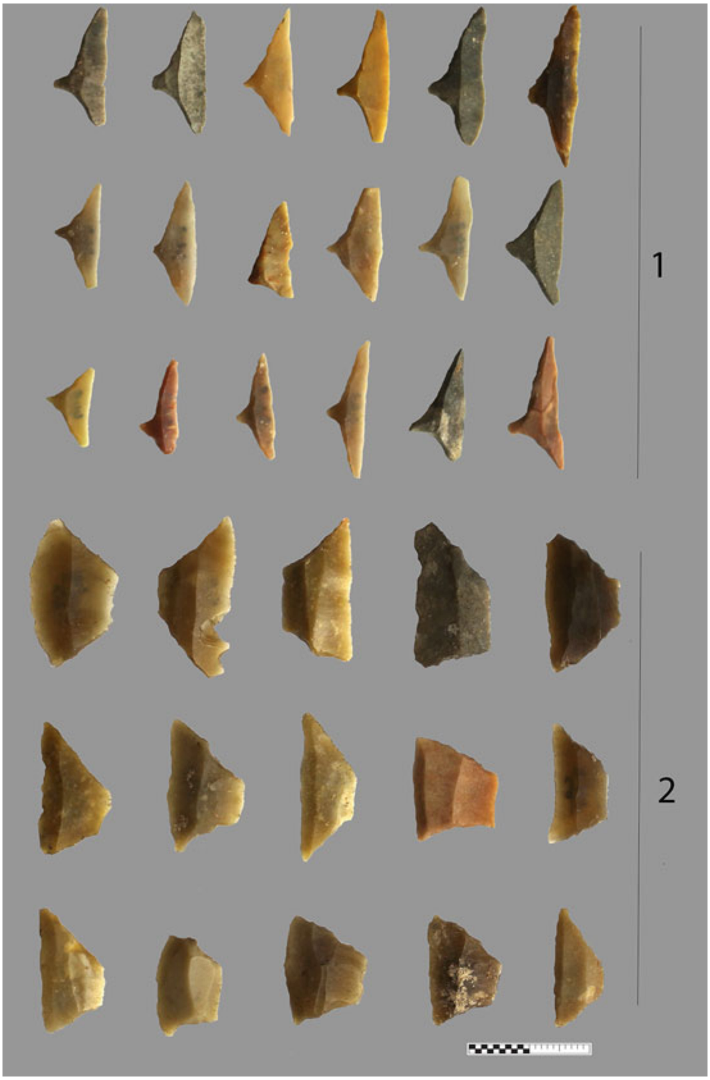

Fig. 3.9 Geometric projectiles: Mesolithic triangles Cocina-type (from Cueva de la Cocina) vs. Neolithic trapezes (from Cova de l'Or)

area (Catalan Cardial, Valencian Cardial), together with these trapezes we can find other geometric projectiles in varying number, such as triangles and crescents with a bifacial retouch: pieces which are absent from the Mesolithic levels of Cueva de la Cocina (from data obtained in recent revisions). On this basis, the bifacial retouch could be considered an Early Neolithic stylistic trait, which is the current general opinion, although this could vary with time, as stated above. We find a similar situation with Montclus/Jean-Cros projectiles typical in southern France.

These types of pieces, of trapezoid or triangular shape with concave sides, with an inverse semi-abrupt retouch and a direct flat retouch (Guilaine 1979), have been traditionally considered an indication of the Neolithic (Cardial or Epicardial); but this is currently starting to be questioned (Valdeyron et al. 2013: 384, 389). In the case of the bifacial retouch we need to clarify what the implied technical attributes are, on which specific projectiles it is found, and in what archaeological contexts.

In relation with the trapezes linked with the Early Neolithic in Iberia, another singular technological trait deserves mention: the alternate directions that can be observed in the retouches (direct on one side, inverse on the other), as documented in assemblages from the Catalonia, Valencia and Andalusia regions. This distinguishing feature has at times been cited to differentiate between Neolithic or Mesolithic trapezes (obviously trapezes of Mesolithic phase A or Cocina I, from the 7th millennium cal BC) in sites that contain human activities linked with both stages, without a clear stratigraphic separation (cf. Cueva de Nerja; Aura et al. 2013). In the French Provence, certain technical peculiarities also permit us to attribute geometric projectiles to the Mesolithic or the Neolithic. The presence of an abrupt crossed retouch in the large truncation, together with a flat retouch from the short truncation, is considered a Castelnovian trait. The abrupt or semi-abrupt inverse retouch, particularly in trapezes but also in triangles, together with a flat direct retouch, is characteristic of Neolithic Cardial projectiles (Binder 2000: 125, 135–136).

In contrast with the stylistic differences which can be detected in the Iberian and French areas, in southern Italy the lithic industry of the Early Neolithic *Impressa* shows a close proximity with local Castelnovian series (Perrin and Binder 2014). Both share knapping techniques (one-side removal, pressure and indirect percussion), products (small blades and bladelets), breaking techniques (microburin) and a predominance of trapezes. All this information seems conducive to accepting the existence of direct links between both industries: that is, technological transfers from Castelnovian to *Impressa*, which raises the question of the precise area where these entities coincided and had contact: a question impossible to determine from current archaeological data. This contact needs to be sought in other areas prior to 6000/5900 cal BC, a task which presents considerable difficulties at the present (Perrin and Binder 2014: 277).

The situation in the North of Italy is not dissimilar to that in the South. Lithic industries belonging to the Early Neolithic groups (Fiorano, Vhò, Gaban, etc.) show certain traits very similar to the Castelnovian. A suggested hypothesis to explain this would propose two stages of colonisation of Northern Italy from an external territory: first by Castelnovian Mesolithic groups, and subsequently by the same groups after their neolithisation (Perrin 2009). The similarities between both industries, especially in the technological aspects, nonetheless do not hide small evolutionary differences, observable for example in the main site of Gaban (Perrin 2006), a rockshelter located in the Adigio valley that manifests occupation levels in both the Late Mesolithic and Early Neolithic (Gaban group). One instance is the apparent preference of Neolithic knappers for selecting the narrow side of the cores for the front of the blade debitage, a detail seemingly irrelevant to the Castelnovian knappers. It is also noticeable that although the geometric armatures in both cases include trapezes with oblique truncations and the trihedral apex preserved, the Castelnovian symmetric trapeze shapes evolve into larger, asymmetric pieces in the Early Neolithic.

It is therefore evident that the Italian lithic industries offer little help in separating the Mesolithic and Neolithic identities. Distinctive lithic traits are more noticeable in Mediterranean Iberia and in southeast France, showing clearer aspects of style and contributing more to the task of establishing identity.

3.5 Conclusion

The three main subjects addressed in this work, linked by the overall concept of identity, find their epilogue in a paleobiological rather than archaeological context, and especially in the context of molecular paleogenetics. We began by explaining Mesolithic and Neolithic settlement from a demo-cultural perspective, that is, considering Mesolithic and Neolithic as distinct groups. We observed that at the beginning of the neolithisation process in West Mediterranean Europe, a number of areas reflect a complete lack of Mesolithic population (as seen in Catalonia, Andalusia, the Liguria-Provence territories and the south of Italy). This absence of Mesolithic settlements prior to the Neolithic arrival can range from more than 1000 years, as in Catalonia, to 400 years in the case of the first Neolithic nuclei in the central-southern Valencian region, and the Andalusian coast of Malaga, according to these well-documented examples in Mediterranean Iberia. By 'absence' we refer to the total lack of archaeological data which can be associated with any of the established facies of the Late Mesolithic (Cocina facies, phases A, B or both, in the Iberian Mediterranean area), or with any other contexts or assemblages whose radiocarbon dates would fall within the same chronological interval (at least between 6500 and 5500 cal BC).

The consideration of different Mesolithic and Neolithic peopling led us to ponder the possibility of contact and interaction between them. This is inherent to a diffusionist view of neolithisation, which takes for granted, as pointed out by Perrin (2013: 360), the contemporaneity of and encounters between Mesolithic and Neolithic groups. Current information only allows us to confirm this coexistence at a distance, rather than in proximity. Citing again Mediterranean Iberia, the most ancient radiocarbon dates of the Early Neolithic and the most recent from the Late Mesolithic overlap a mere 28 years, at a maximum. If we extend the territorial scale within Iberia, the most we can say with certainty is that when the first Neolithic pioneers arrive on the shores of Catalonia, some Mesolithic groups inhabit areas of the south-western Pyrenees and of the Cantabrian coast.

Confirmation of Neolithic/Mesolithic contact has been sought through the identification of eventual technological transfers, in particular lithics, encompassing particular retouch techniques, specific projectile types, etc. The problem is that the possibly identified transfers (elements) and their direction (from whom to whom) still lack reliable confirmation from a taphonomic viewpoint (a thorough review of sites and archaeological sequences) and chronologically (the application of filters to old radiocarbon dates and the selection of new accurate samples). These methodological principles are extensive to the question of contemporaneity, and of course to any similar archaeological problem.

Regarding the contrast between Mesolithic and Neolithic identities, it seems evident that in the area of lithic production—the respective lithic industries—certain stylistic distinctive traits exist, most noticeably in Mediterranean Iberia and southeast France. If style is the materialisation of cultural identity, we can conclude that Mesolithic and Neolithic groups, at least in these territories, represent culturally different populations. The following question would be whether the archaeological difference or 'break' is synonymous with a population break: that is, if there is a break in parental filiation. The response, and here we open the epilogue, begins to be resolved by the paleobiological discipline, in particular through ancient DNA analysis. Certainly these analyses, and especially of the mitochondrial DNA, are bringing to light an interesting series of data worthy of mention. We conclude with an overview of these details, logically in relation to the Western Mediterranean and particularly Mediterranean Iberia: a region that holds the best information currently available (Sampietro et al. 2007; Fernández Domínguez et al. 2010; Gamba et al. 2012, 2013; Lacan et al. 2014; Olalde et al. 2015).

In the first place it is important to consider the significant difference between the genetic composition of the Iberian Neolithic population, at least in the northeast of the peninsula, and the current population of the same territory, a recurrent feature in other areas both in and out of Europe (Fernández Domínguez et al. 2010, 2014; Gamba et al. 2012). This calls for a revision of all conclusions about demographic movements in the past, derived from genetic studies of current populations (cf. Richards et al. 2000).

Secondly, we should underline the differences between the mitochondrial types (haplogroups) of the Mesolithic and Neolithic groups. While recognising the scarcity of the Mesolithic samples (published: Fernández Domínguez et al. 2010; Gamba et al. 2013), provided only by a few individuals from the Valencian El Collao site (8th and first half of the 7th millennium cal BC), the genetic disagreement is nonetheless evident when comparing this site with some Early Neolithic Cardial samples from Can Sadurní in the Catalonia Neolithic nucleus (second half of the 6th millennium cal BC), and Cueva de Chaves (same period), located in the Upper Aragon region and indicative of the rapid inland penetration of Early Neolithic groups. The distinctive haplogroups of the Cardial Neolithic are N* and K (Gamba et al. 2012), not found yet in Iberian Mesolithic samples, but present in some individuals from the Pre-pottery Neolithic (PPNB) in Siria (Fernández Domínguez et al. 2013, 2014). This finding suggests the possibility of a Neolithic genetic contribution that would have reached the Iberian coast from the Near East, strengthening old and recently renewed ideas that see the Mediterranean neolithisation as a largely demo-cultural process.

In the third place, the same haplogroups N* and K appear in samples from the Post-Cardial Neolithic site of Sant Pau del Camp (frontier 5th–4th millennia cal BC) situated in the Barcelona plain, indicating a certain degree of genetic continuity during the Neolithic in the Northeast area of Iberia (Gamba et al. 2012). Nevertheless mitochondrial DNA data provided by the analysis of some skeletons of the Epicardial/Postcardial Early Neolithic in Cova de l'Avellaner (5th millennium cal BC), situated just outside the eastern Catalan Pre-Pyrenees, would not support this continuity according to the haplogroups identified (K1a, H3, T2b, U5), all supposedly introduced into Europe in a pre-Neolithic period (Lacan et al. 2014). This same discontinuity is suggested by some samples from Camí de Can Grau (Middle/Recent Catalan Neolithic: second half of the 4th millennium cal BC; Sampietro et al. 2007). In this particular case, considering the chronological distance from the Early Cardial Neolithic, the differences detected in genetic composition, and especially the loss of rare haplogroups like N*, could be explained by genetic drift (Gamba et al. 2012).

In the case of Cova de l'Avellaner there could be other reasons. This site has also provided results including the Y chromosome, of exclusively paternal transmission, in addition to maternal mitochondrial DNA. In contrast with the mitochondrial haplogroups, those with chromosome Y (G2a, E1b1b1a1b) are considered linked with the Neolithic expansion. The sum of information from this site would suggest an early maternal origin for the population there present, in accordance with mitochondrial lineages probably arriving in Europe at the end of the Paleolithic, and a more recent paternal origin linked with Y chromosome lineages associated with the Neolithic spread. This could suggest that the diffusion of 'men' during the Neolithic transition might have been more important than that of 'women' (Lacan et al. 2014). In the same conjectural vein, might it not be possible that the mitochondrial details of Cova de l'Avellaner, site located in the periphery or expansion area of the Catalan Neolithic nucleus, could be an indication of Neolithic-Mesolithic contact?

Recently the complete genome of a neolithic individual from Cova Bonica de Vallirana (Barcelona), dated in 5400 cal BC (Cardial Early Neolithic), has been obtained, as well as some partial information of the nuclear DNA of other individuals of the same chronology in the Mediterranean area of Iberia: Cova de l'Or (Alicante) and Cova de la Sarsa (Valencia) (Olalde et al. 2015). These data, especially from Cova Bonica, in addition to revealing the genetic relationship between the Cardial Neolithic in Iberia and the LBK Neolithic in Central Europe, explained by both groups derive from an ancient and common population located in or around the Balkan peninsula; such data, again, would show that the Iberian cardial genome also entails a discernible genetic imprinting due to hunter-gatherers, which appears not to be acquired locally, that is, by hybridisation with Iberian Mesolithic populations.

From a genetic standpoint it is not yet possible to outline a conclusive population panorama for the neolithisation period of Mediterranean Iberia and other European areas, due to the scarcity and bias of the samples studied. Nonetheless it can be fairly stated that we are starting to tie up loose ends, and to perceive a complexity in the genetic filiations which contrasts with the relatively simplistic current demo-cultural models.

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Part II
Reconstructing Times and Modeling Processes

Chapter 4
Timing the Western Mediterranean Last Hunter-Gatherers and First Farmers

Oreto García-Puchol, Agustín A. Diez Castillo, and Salvador Pardo-Gordó

4.1 Introduction

Timing the Neolithic transition is a key question for understanding the nature of this crucial process in human evolutionary history. While there is a general consensus to consider the Near East as the original focus of the neolithisation of Europe, some serious disagreements appear in relation to the expansion mechanisms; focused specially on the role that indigenous groups played in them (demic—Ammerman and Cavalli-Sforza 1984; vs. cultural models—Whittle 1996; Zvelebil 1986). The spread of domestic plants and animals from the Near East towards Western Europe follows two main routes: through the Danube corridor and via the Mediterranean Sea. Several works have tried to investigate the process using different approaches based on mathematical models (Ammerman and Cavalli-Sforza 1971; Fort 2012), in which radiocarbon dates constitute a determining variable. This attention to radiocarbon dates has produced several compilations of 14C data, not only for the whole continent (Pinhasi and Von Cramon Taubadel 2009; Shennan et al. 2013), but also some more intensive research in smaller regions (Fiorentino et al. 2013; Isern et al. 2014; Manen and Sabatier 2003).

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In recent years, advances in radiocarbon dating techniques have allowed researchers to improve the selection process of radiocarbon samples. At the same time some researchers have focused their attention on the taphonomic processes that affect the samples, and consequently on the need to maximise care when selecting them (Bernabeu 2006; Bernabeu et al. 2001; Zilhão 2011). Consequently, we should point out that mapping the Neolithic expansion requires giving special attention to dates derived from undisputed domestic remains (Zilhão 2001, 2011; Bernabeu 2014b).

Our goal in the present work is to time the neolithisation process in the Western Mediterranean, through the compilation and subsequent filtering of the current radiocarbon dataset from late Mesolithic to early Neolithic (ca. 7000–5000 cal BC), applying a 'longue durée' view. We focus our interest on four main regions that include Italy, Southern France, Spain and Portugal. Despite our attention to these wide regions, we are conscious of the importance of comparison with local dynamics, for a better approach to the complexity the process involves. Although some interesting new insights have been published recently (Linstädter et al. 2012), we do not consider the north-west African territories in the same detail, due to the still scarce and dispersed information.

From a general perspective, most researchers coincide in the relevance of a demic diffusion model in the spread of food production economies through Western Mediterranean territories (Zilhão 2001, 2003; Guilaine 2001, 2013; Guilaine and Manen 2007; Bernabeu and Martí 2014; Bernabeu et al. 2014; García Puchol et al. 2009); Zilhão (2001) describes a pioneer movement along the coast reflecting the fast spread of food production economies. J. Guilaine claims that archaeological data seem to show an 'arrythmic model' on a spatial and temporal scale.

The dual model proposed in Valencia (eastern Mediterranean region of the Iberian Peninsula) implies a mixed model that assumes the arrival of Neolithic pioneers and describes the possibilities of interaction with local hunter-gatherers (Bernabeu and Martí 2014; Juan-Cabanilles and Martí 2002). In contrast, some other authors are in favour of a cultural transmission process through Mesolithic networks based on the Iberian archaeological context (Cruz Berrocal 2012; Diaz del Rio 2011; Vicent 1997).

In this paper, both the possibility of a gradual process in the adoption of farming and herding and the interaction between new-coming farmers and local hunter-gatherer groups will be explored; taking into account the current 14C dates data base, introducing a general perspective and regional zoom that will allow us to add some specific and interesting features to the debate.

4.2 Archaeological Background

The Western Mediterranean area during the Neolithisation process was a complex mosaic of territories and landscapes. The general climatic conditions were temperate with hot and dry summers and wetter conditions in winter than today

(Frigola et al. 2007). Some differences are observed according to latitude and altitude locations and distance from the sea. Palaeoecological data at the beginning of the Atlantic period point to the climactic moment of Mediterranean deciduous forest. Recent works focusing on palaeoclimatic proxies in the region show differences between maritime and continental data, in order to evaluate how the 8.2 ky cal BP event would affect ecological conditions in the area, and consequently if these had an impact on socioecological dynamics. In this sense, and considering the variability in both proxy resolutions and the regions affected, it does not seem reasonable to postulate a general impact unequivocally correlated with archaeological data (Cortés et al. 2012; Bernabeu et al. 2014b). On the other hand, the Neolithic advance from Southern Italy with a chronological East-West gradient took place after this abrupt palaeoclimatic event. Consequently, the 8.2 ky cal BP effects will only be visible in Mesolithic population dynamics.

Information about last hunter-gatherers in Western Mediterranean regions provides variable regional data, due probably to several factors such as a different intensity of research, unequal visibility and taphonomic process, but also to the spatial variability of human settlement during this period. The late Mesolithic techno-complexes in the Western Mediterranean, from the beginning of the seventh millennium cal BC, are characterised by the irruption of blade technology and trapezes through the region: with distinct locations in specific areas of Tunisia and Algeria (Upper Capsien, Tixier 1976; Rahmani 2003); the north of Italy (Eastern Po plain and Alpine area, Biagi 2003; Franco 2011; Perrin 2006); the Provence region (Southern France); the East coast of the Iberian peninsula and the Ebro corridor (Spain); and the estuarine areas of the Tagus and Sado and the South Atlantic coast of Portugal (Carvalho 2009).

While it is possible to observe some concentrations of sites, other large regions show an unquestionable lack of data. This lack of data has been linked with the taphonomic process (erosion), which could have affected some deposits at the time, as well as with the rising sea level, that could have covered an important number of sites (Berger and Guilaine 2009; Binder 2000). Blade technology and trapezes are recognised in a wide area with a significant location along the Mediterranean coast, but also in inland and mountainous areas (Ebro valley or Alpine area), showing similar patterns such as the use of pressure knapping techniques (Binder et al. 2012). Consequently characteristic regular bladelets with thin sections are common, and the most regular of them are selected for making microliths by microburin technique. Some changes in lithic tools with the passage of time from trapezes to triangles (Cocina type/Muge type) have been pointed out in the western territories (Carvalho 2009; Martí et al. 2009). Nevertheless, some regions currently indicate particular knapping traditions with scarce or absence of blades and trapezes (Cantabria region, eastern Languedoc and Pyrenean piedmont).

Elsewhere there are concentrations of sites related to the exploitation of marine resources, but this is not the case in the Mediterranean area. While both the Tagus and Cantabrian coasts present an important density of sites in estuarine areas (shell-middens), the subsistence patterns in the Mediterranean regions considered here indicate a minor impact of marine resources. The stable isotope analyses conducted in human remains are still scarce but provide some indications of marine resources, with unequal presence among sites but also intrasite (Salazar-García et al. 2014). Open air sites and caves provide information about the existence of a seasonal subsistence pattern that includes coastal and inner territories in some areas (Valencian region, Eastern Spain, Martí et al. 2009). The existence of necropolis (well known in Portugal shell-middens and present in the Valencian region—Collado site) indicates a higher territorial stability.

The Eastern/Western gradient in Neolithic expansion is observed across regions with differing densities of occupation. Thus, in the journey towards the west, different situations can be observed. Southern Italy provides little information about the last Mesolithic settlements, because data come only from a few sites such as Uzzo Cave in Sicily or Latronico 3 in Basilicata (Collina 2009; Pipperno et al. 1980). In Northern Italy the best known site is Piazzana (Garfagnana, Toscana) with a typical Castelnovian industry. The Eastern Po plain and Alpine areas concentrate several sites with Mesolithic deposits such as Romagnano III and Gaban (Kozlowski and Dalmieri 2000; Perrin 2006). In Southern France the number of sites is still low and they are spread across different inner and coastal territories of the Provenze/Côte d'Azur region with typical Castelnovian industries in sites such as Font des Pigeons, Mourre du Sève and Lalo (Binder et al. 2012). In several areas of the Iberian Peninsula, late Mesolithic settlements are numerous: mainly along the Mediterranean coast of Iberia (Valencian region)—Cocina cave, Benámer, Falguera rockshelter, Casa Corona, Mas Nou (Martí et al. 2009); the Ebro corridor (Aragon autonomous region and Basque country)—Botiquería dels Moros, Costalena, Cabezo de la Cruz, Forcas II (Utrilla et al. 2009) and Mendandia, Atxoste (Alday and Cava 2009); and the Atlantic coast of Portugal—Moita da Sebastiao, Cabeço de Amoreiras (Bicho et al. 2011; Carvalho 2009).

The agricultural way of life appears in the south-eastern area of Italy (Apulia) at the end of the seventh millennium cal BC. Several villages show a new settlement pattern that reveals some features related to a new subsistence model. Cultural material also reflects the appearance of new elements such as pottery, linked with the so-called impressed cultural wares. The use of impressed techniques in decoration patterns using shells such as *Cardium edule*, fingers and other instruments is widely extended along the Western Mediterranean area, together with the arrival of food producing economies. Some authors have pointed out the scarcity of late Mesolithic sites in Italy, which moreover are concentrated in a few northern areas (Biagi 2003). In the south, the number of Mesolithic sites is very low compared with the high number of Early Neolithic sites. These are very visible in the landscape due to the presence of some ditched villages of between 100 m and 300 m diameter (common in central and northern Puglia), but also of open villages and tiny hamlets (Robb 2007, Pearce 2013). Some key sites in Southern Italy are Trassano, Torre Sabea, Scamuso, Rendina and Favella. Within a few centuries, the Neolithic arrive at the central territories of Italy and the Ligurian coast (Arene Candide). In fact, the spread of the first farming communities is very fast along the Western Mediterranean territories, as stated by Zilhão (2001) to explain the rapidity of the very early arrival of the Neolithic to the Atlantic shores of Portugal.

In southern France the spread shows two traditions, where the early impressed tradition is present in a small number of sites located in the Ligurian area (Pendimoun, Binder and Sénépart 2010; Binder et al. 2014) and the Languedoc province (Pont de Roque Haute, Potiragnes, Leucate, Guilaine et al. 2007) that reflect some links with the Ligurian Neolithic in Italy (Arene Candide). The *Cardial* tradition appears towards the middle of the sixth millennium cal BC throughout the entire coastal territories, with characteristic open air sites and strategic occupation of caves and rock shelters. Despite the low number of late Mesolithic sites excavated, some recent radiocarbon dates allow some scholars to propose the continuity of hunter-gatherer economies at the beginning of the sixth millennium cal BC (Baume de Monclus, Perrin et al. 2009).

The first farmers and herders in the Iberian Peninsula appear earlier along the Mediterranean coast and some inland areas (Ebro valley). Current research points out the recognition of a major diversity in the first ceramic styles, represented mainly by the Cardial tradition well known in several territories such as Catalonia, Aragon and the Valencia region (Bernabeu and Martí 2014). In the Valencian region some similarities with the early impressed ware tradition described in Southern France have been noted at two sites: El Barranquet and Mas d'Is, both dated towards the middle of the sixth millennium cal BC (Bernabeu and Martí 2014). The number of *Cardial* sites (through the second half of the millennium) is notable, reflecting a settlement pattern where some open air hamlets in productive lands are documented, in addition to other strategic occupations of caves. In the Northern Iberian areas, the spread along the Ebro corridor is also fast according to the current radiocarbon dataset.

In contrast to the scarcity of late Mesolithic settlements noted in Italian and French territories, Iberia reflects a great variety of situations over the different areas considered. Whereas in Catalonia late Mesolithic sites have not been discovered, in the Ebro corridor, the Valencian region and the Cantabrian Coast there are many, with several micro-regions that reflect the persistence of Mesolithic groups at least until the end of the sixth millennium cal BC, creating territories where it is possible to sustain the hypothesis of an acculturation/assimilation process (Juan-Cabanilles and García Puchol 2013). On the other hand, the persistence of forager subsistence patterns in the Cantabrian coast territories continues until almost the fifth millennium BC. The arrival of farming practices in the Southern Mediterranean shores of Iberia is described as a very fast process, as indicated by recent direct radiocarbon dates of domestic animal bones found in both Nerja Cave, Málaga (Aura et al. 2013) and Carigüela Cave, Granada (Medved 2013). The pottery decoration techniques described at Nerja Cave have given rise to a suggested hypothesis of several expansion routes (such as the possibility of a Mahgreb route) in order to explain the peculiarities documented (the scarce incidence of cardial decoration) and the antiquity of the radiocarbon dates obtained (Aura et al. 2013). For the moment, more data from North African early Neolithic sites are required to test this hypothesis.

In central-south Portugal there is a very high concentration of shell-midden sites in coastal areas and estuarine territories, with both domestic and ritual features such as necropolis. The first Neolithic sites (linked to the cardial complex) seem to take up areas uninhabited by Mesolithic populations (Zilhão 2003). The hypothesis (maritime pioneer colonisation) pointed out by Zilhão (2001) would explain the rapidity of the Neolithic expansion along the Western Mediterranean coast as far as the Atlantic regions of Iberia. The discussion about the existence of contacts between Mesolithic and Neolithic populations and their role in the Neolithisation process remains open.

4.3 Western Mediterranean Radiocarbon Dataset

In this work we have compiled the dataset of the Western Mediterranean region, applying several filters in order to produce a finer resolution dataset for mapping the timing of the Neolithisation process. In order to do that we have in the first place compiled all radiocarbon dates (between 8000 and 6000 bp) with a revised archaeological context and a standard deviation equal or inferior to 100 years. As we have already pointed out we consider four wide regions from the Central to Western Mediterranean European territories: Italy, Southern France (Midy-Pirennees, Languedoc-Roussillon, Provence/Cote d'Azur, Rhone/Alpes and Corse), Spain and Portugal. The information is taken from several radiocarbon compilation works for both entire regions and specific areas (Bernabeu et al. 2014b; Bicho et al. 2011; Binder and Sénépart 2010; Carvalho 2009; Dini et al. 2008; Fano et al. 2014; Fiorentino et al. 2013, Manen and Sabatier 2003; Medved 2013; Perrin 2006; Perrin et al. 2009; Rojo et al. 2012, http://www.arch.cam.ac.uk/research/projects/bova-marina/bmap-dates; Van Willigen et al. 2009). We also referred to some radiocarbon databases online (such as Galate (2011): Banadora—http://www.archeometrie.mom.fr/banadora/, Radon—Hinz et al. 2012).

Our database reflects several descriptive aspects such as the nature of the sample (material, species), size of the sample, single or aggregate, with the idea of being able to apply different filters to investigate the degree of resolution on different spatial and chronological scales. 1060 radiocarbon dates have been recovered in the entire area (Table 4.1). At the moment, the most complete radiocarbon datasets correspond to Spain and Italy. Both regions coincide in a high number of Neolithic sites, while there is an important difference in the number of Mesolithic dated sites although in Italy mainly correspond to the Neolithic. France and Portugal again present fewer sites, but with an interesting difference: more Mesolithic sites with radiocarbon dates in Portugal (27/19).

If we go deeper into the samples characteristics, we find new specific patterns that make it difficult to compare the degree of resolution region by region. This aspect is relevant in our work due to the fact that we are trying to build an accurate time framework from current radiocarbon datasets. Accordingly, we have applied some filters at different scales (general and regional) with the idea of comparing and discussing the results. Several authors have insisted on the importance of selecting short-lived samples in order to produce more accurate data, despite other problems linked with taphonomic processes that affect the samples (Bernabeu et al. 2001;

Table 4.1 14C radiocarbon dataset by materials and regions

	Portugal	Spain	France	Italy	Total
Total	145	455	153	307	1060
Charcoal	23	168	73	137	401
Charcoal short live	4	9	0	2	15
Bone	14	103	28	10	155
Domestic bone	6	31	12	3	52
Human bone	26	33	6	7	72
Ornament bone	2	1	0	0	3
Seed/fruit	0	16	1	9	26
Domestic seed	0	69	7	21	97
Shell	70	20	8	1	99
Pollen	0	2	0	0	2
Indeterminate	0	3	18	117	138
Site number	40	130	35	100	305
Early Neolithic	19	84	31	89	223
Late Mesolithic	27	60	15	15	117

Zilhão 2001, 2011). In the case of Neolithic assemblages, it is obvious that remains of domestic plants and animals allow direct dating of archaeological elements related to the neolithisation process. Other short-life samples coming from levels with domestic remains can also be good indicators. In Mesolithic contexts a similar link can be obtained from human bones, wild bones with anthropogenic marks or seed/fruits clearly linked with human consumption.

Following these remark it is important to keep in mind how old wood effects can affect charcoal samples, making it necessary to identify and select short-life samples with a clear archaeological context. The potential for mistakes when chronological inference is based on radiocarbon dates taken from different materials coming from the same pits/levels (unidentified charcoal/bone/cereals) is exemplified by the Ambrona site, Spain (Bernabeu et al. 2014). The marine reservoir effect also reflects problems linked with the accuracy of estimated dating from marine shells and human bones (Ascough et al. 2005).

Table 4.1 exhibits the classification by material of all radiocarbon dates compiled in this work. We have separated several relevant materials such as domestic bones and seeds that will be determinant in the discussion. Some comments can be made regarding the importance of shell samples in Portuguese sites, or the predominance of charcoal samples (mainly from unidentified charcoal) in regions other than Spain. We should mention also the high proportion of indeterminate samples noted in Italy, mainly due to our difficulties in obtaining details about this kind of information.

The archaeological background, indicated in the reference sources, provides data for considering either a Mesolithic or a Neolithic context. The number of sites with radiocarbon dates reaches a total of 305; of these 223 have Early Neolithic contexts and 117 have Mesolithic. Spain (130) and Italy (100) have the largest number of

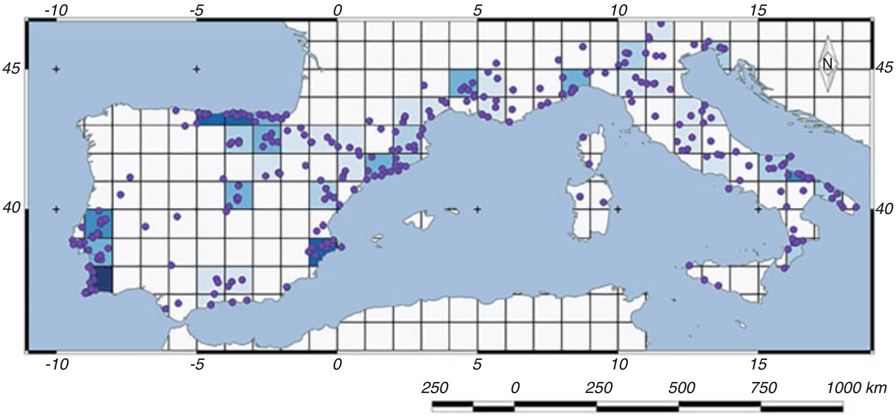


Fig. 4.1 Western Europe map with the indication of site distribution densities in the entire area

sites by region, as against Portugal and France with 40 and 35, respectively. Nevertheless, if we compare densities, few differences are observed among the regions (nearly three sites per 10 km^2 in Italy, Southern France and Spain) except in the case of Portugal (close to 5 sites per 10 km^2). From these data we could maintain that, apparently at least, in a broad spatial approach no bias exists in the representation of dated sites.

Fig. 4.1 presents site distribution densities in the entire area, reflecting a dispersal pattern for Italy and France (inland and coastal territories) and a more concentrated image in Spain and Portugal, where sites mainly appear in coastal areas and the Ebro corridor. Differences appear when we move to the regional level, where a huge variability between Mesolithic and Neolithic records can be observed, mainly in Italy and France. In this case there is a predominance of Neolithic sites, and especially in Italy.

As several authors (Combré and Robinson 2014) have pointed out, other biases that can affect the composition of dated samples include the visibility of sites according to their particular nature (structural components, materials, intensity of occupation, location), research tradition, and whether or not and to what extent systematic excavations been carried out in a particular area. Keeping in mind all of these considerations, we have decided to take into account the entire dataset despite its random character; even if when zoom analysis is conducted on a regional scale the results have to be discussed in accordance with the lessened significance due to the resultant reduction of the samples (Williams 2012).

4.4 Building Chronologies

We have explained the criteria used in our selection of radiocarbon dataset for the area studied, and its value as a proxy for discussing population patterns throughout the Neolithisation process. As stated we work with a compilation of 1060 selected radiocarbon dates, with the goal of conducting several analyses to map chronologically the last hunter-gatherers and the first farmer settlements in the entire area. The first analysis carried out consisted of building summed calibrated date probability distributions, in accordance with the premise that such data constitute a quasi-random sample to obtain information about population dynamics (Shennan 2012).

Several works published in recent years focus their interest on this type of analysis, considering several spatial and temporal scales (Gamble et al. 2005), sometimes in order to investigate population dynamics of Neolithisation in different regions of Europe (Shennan 2012; Shennan et al. 2013). Some criticism persists, chiefly about four key aspects: sample size (Williams 2012), fluctuations in the radiocarbon calibration curve (Bamforth and Grund 2012), the impact of taphonomic processes that affect archaeological sites, and the effects of differences in research interest (Combré and Robinson 2014; Surovell et al. 2009).

Our analysis is conducted applying certain filters of 14C dates to discuss the results at different spatial levels. Several authors apply a first filter, in order to eliminate the bias produced by multi-sampling sites, calculating a unique date by phase and site (Shennan et al. 2013). We have preferred not to apply this filter, due to the problems involved in controlling all the published information regarding different stratigraphic contexts within the wide framework studied. However we selected other types of filters and comparative analyses in order to mitigate the effects produced by this bias. In the first place we only used dates coming from a clear archaeological context and with a standard deviation equal or inferior to 100 (resulting 1060 dates), and we have removed all marine and human bone samples that can be affected by fluctuations of the reservoir effect (resulting 940 dates)—Ascough et al. 2005; Soares and Dias 2006. Then we applied a second filter to the dataset, consisting in using only single short-life samples that will allow us to compare the results on a subcontinental as well as a regional scale.

Fig. 4.2 shows that no remarkable differences exist in the general picture of density distributions of radiocarbon dates, in those cases where the sample reaches a representative size in both sets of data: all the dates (940), and the short-life ones (455). Given that we are working with dates between 8000 and 6000 bp, our interest

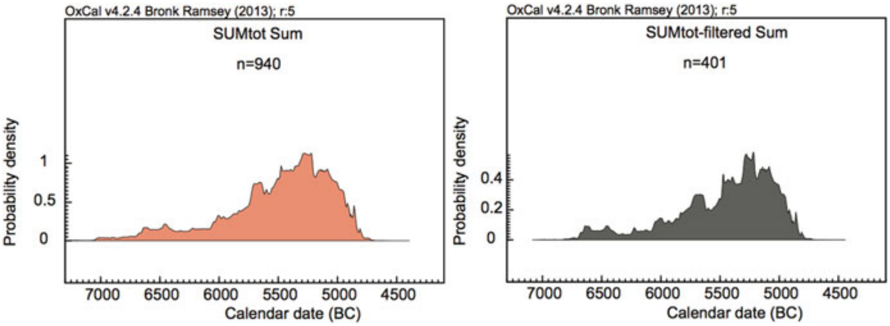


Fig. 4.2 Summed probability distribution in Western Mediterranean: all radiocarbon dates—*left*, single short-life samples radiocarbon dates—*right. We calibrated all the dates using Oxcal Program 4.2 (Bronk Ramsey, 2013) and IntCal13 curve for the Northern Hemisphere (Reimer et al., 2013)*

is in the behaviour exhibited in the middle of this time span, excluding the extremes of the graph (obviously conditioned by the established boundaries). The overall view reflects a great increase in date density coinciding with the arrival of food producing economies to Western Mediterranean territories at the beginning of the sixth millennium cal BC. According with the general East/Western gradient (as shown by short-life radiocarbon samples, Zilhão 2001), we have attempted the comparison on a regional scale (Fig. 4.3). This gradient is also well represented in the rapid increase in density of dates between Italy and Spain, but not in Portugal. The observa4ble rise in Italy coincides with the change of millennia, and in France and Spain in the ensuing centuries. In the case of Spain, another increase is observed at the start of the seventh millennium cal BC, and seems to be related to the number of radiocarbon sites dated for late hunter-gatherer contexts. In Portugal, the number of shell samples is predominant and consequently the sum of probabilities (excluding the shell samples) is not so representative (N = 53).

In any case Portugal provides a particular picture focused on a small region where the number of Mesolithic sites with dates exceeds the Neolithic. After selecting short-lived samples, total numbers there decrease considerably and consequently the results are not significant (Fig. 4.3). Although the number of short-lived samples in the Spain scenario is higher, its variations are pretty much like those of Portugal, Italy and France.

A second analysis was carried out in order to calculate how sites with multiple dates can contribute to a distortion of the results. Using OxCal 4.2 (Bronk Ramsey, 2013) and IntCal13 curve for the Northern Hemisphere (Reimer et al., 2013), we calculated the sum of probabilities of all dates from each site over a specific 200 year range. The image obtained allows us to contrast the sum of probability distributions of all calibrated dates (1 sigma) and sites throughout the entire period, considering all the regions together (Fig. 4.4). We have plotted also the distribution of domestic radiocarbon dates (Fig. 4.4). The effects of applying this filter seemed to moderate the slope created from the arrival of the first domestic evidences (ca. 5800 cal BC), which can be linked with the existence of a larger number of sites with multiple dates. Nevertheless, the growth signal is still detected and coincides with the arrival of domestic economies. Although the comparison between the use of all the dates or applying a short-lived filter seems to produce a more gradual increase pattern, both curves fit a power law distribution (Fig. 4.5).

Summarising, the signal that can be related to the Neolithic Demographic transition (Bocquet-Appel and Bar-Yosef 2008), detected in large parts of Europe using sums of probability distributions of radiocarbon dates (Shennan et al. 2013), is also visible in most of the Western Mediterranean regions considered here. Region by region a gradient towards the Western territories is clearly visible. Despite some regional peculiarities that could be conditioned by sample size, it seems that others, like the major weight of Mesolithic sites in Western regions, can be representative of potential population dynamics in the past. This feature requires a detailed zoom region by region, if we want to get a complete picture of the mechanism which explains the neolithisation process, as has been shown in other areas of the world (Uchillama et al. 2014).

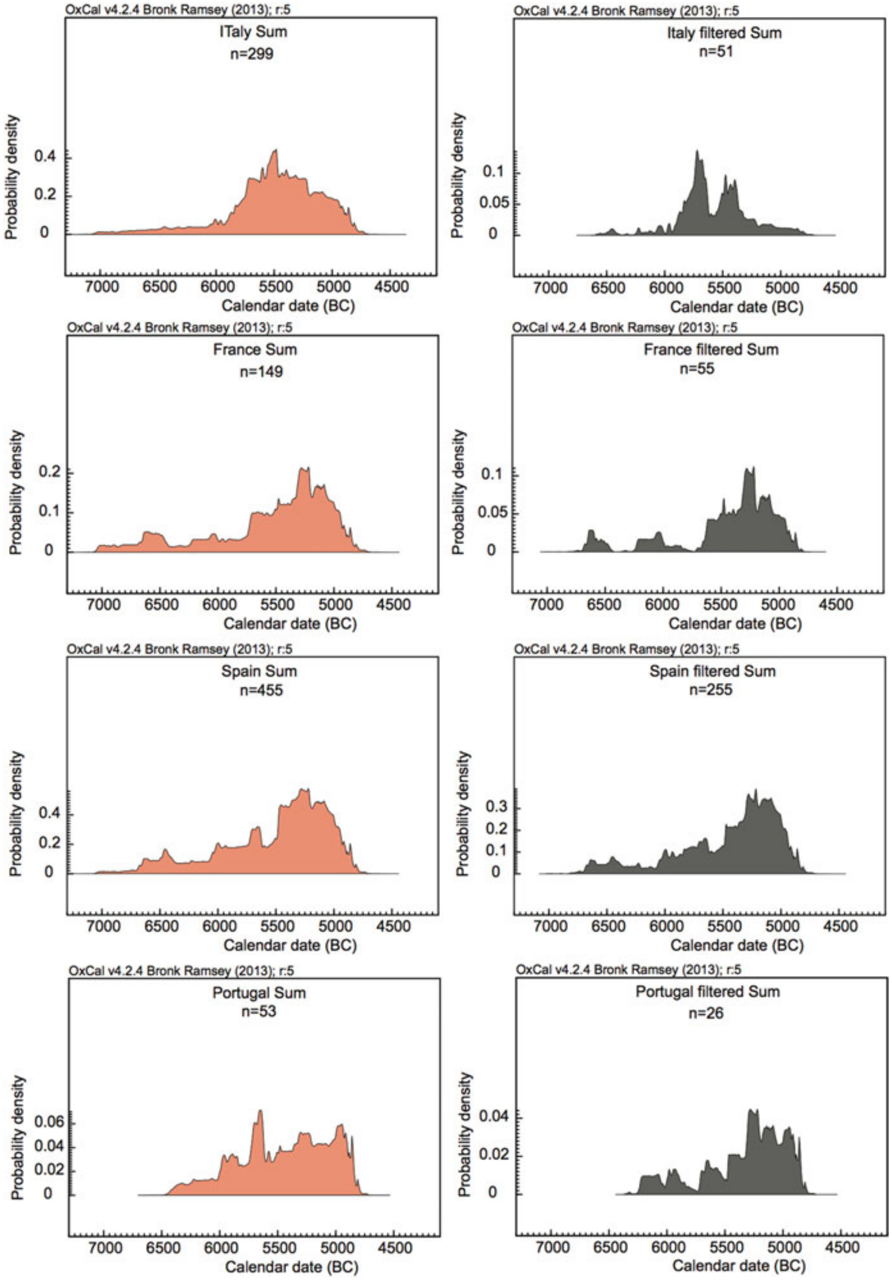


Fig. 4.3 Summed probability distribution in Western Mediterranean by regions: all radiocarbon dates—*left*, single short-life samples—*right*. *We calibrated all the dates using Oxcal Program 4.2 (Bronk Ramsey, 2013) and IntCal13 curve for the Northern Hemisphere (Reimer et al., 2013)*

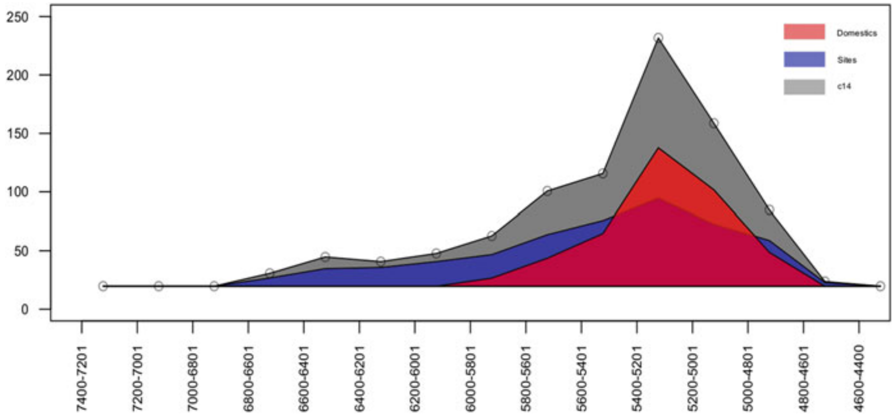


Fig. 4.4 Summed probability distribution: all radiocarbon dates—c14, sites and radiocarbon dates on domestic specimens

4.5 Timing the Neolithisation process in the Western Mediterranean

The Neolithic starts its expansion along the Western Mediterranean coast from Southern Italy, where we find the oldest radiocarbon dates from domestic remains. In this area of the Italian peninsula only the Latronico site presents some Castelnovian levels whose available radiocarbon dates reach the beginning of the sixth millennium cal BC. This scarcity of Mesolithic record contrasts with the antiquity of the first Castelnovian dates in Latronico (layer 63–64), together with the date provided by Grotte de l'Uzzo in Sicily (F, level 13–14), both dated back to the beginnings of the seventh millennium cal BC (Dini et al. 2008).

In order to visualise population dynamics in a broad view from the Mesolithic to the early Neolithic, we built a series of maps where we represent the evolution of densities in radiocarbon dates by intervals of 200 years (Fig. 4.6). We should reiterate that we use radiocarbon dates as a relative proxy for understanding human population dynamics, following similar criteria for filtering dates and discussing some taphonomic and research problems that can affect the results (Shennan et al. 2013).

The maps reflect the densities by interval/site through calibrated dates. We applied similar filters to build sums of probability distributions (all samples with SD equal or inferior to 100), excluding shell samples and human bones affected by the reservoir effect. This last filter especially affects Portuguese samples, so we will try to compensate by adding some comments about the available archaeological information. After calibrating all data (940), we selected a calibration range (68% of probability) and distributed them by intervals of 200 years between 7200 and 4800 cal BC. We interpolated the probability of each site by intervals using the sum of their probabilities in the range considered through R (R Core Team 2014). The

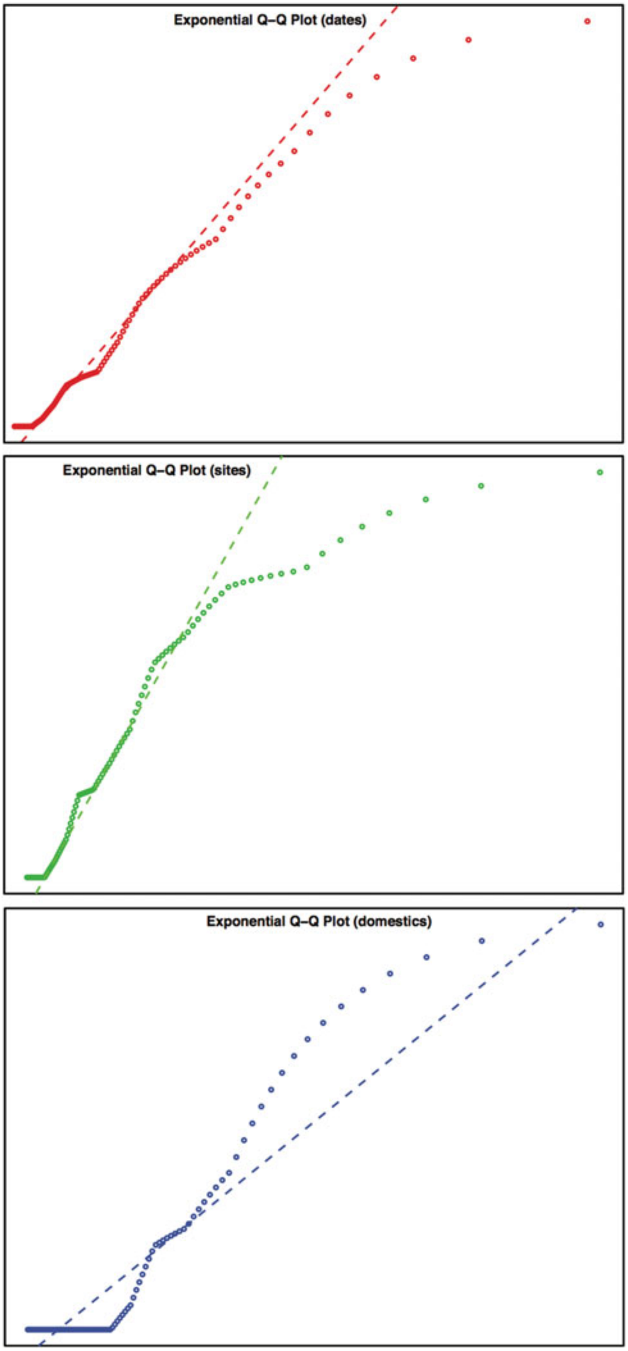


Fig. 4.5 Power law fit—*from top to bottom*: all radiocarbon dates, sites and radiocarbon dates on domestic specimens–Domestics

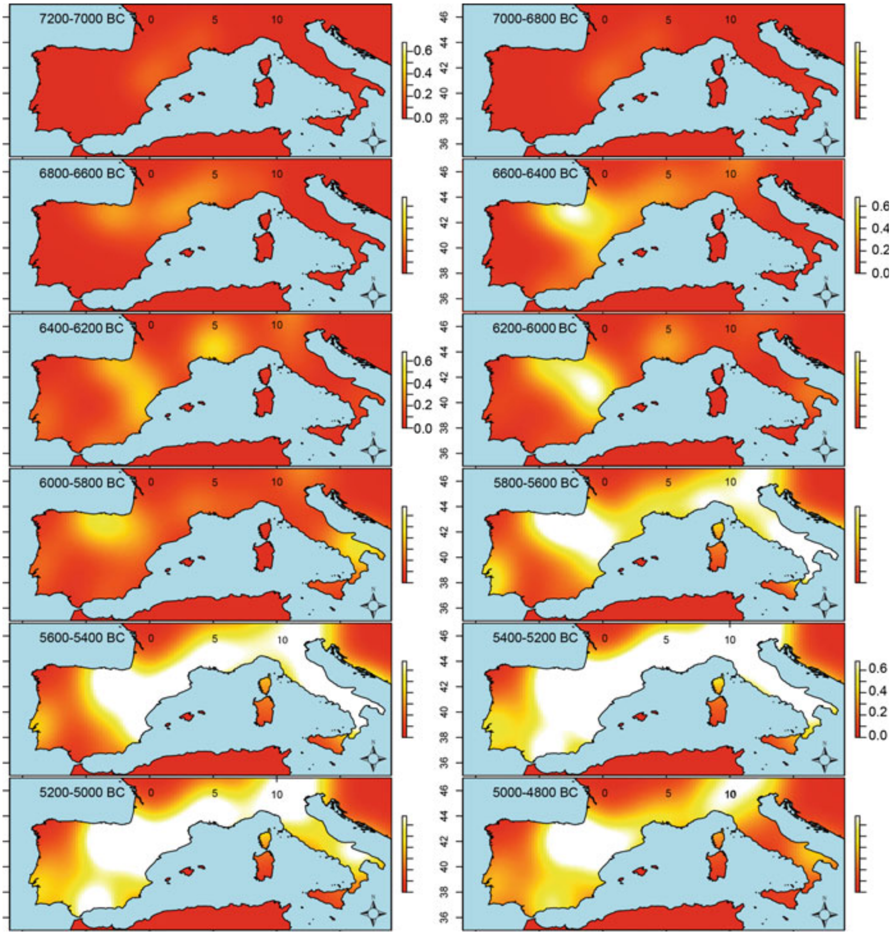


Fig. 4.6 Radiocarbon density maps—200 years interval

resulting maps show a diachronic perspective of radiocarbon date densities encompassed between the appearance of the Mesolithic with trapezes complex to the arrival and first expansion of food production economies throughout the Western Mediterranean region.

Taking into account that the first maps show residual densities of dates, we begin our description considering the interval 6800–6000 cal BC, where it is possible to distinguish some low densities of probabilities concentrated in two main areas: Eastern Cantabrian coast/Upper Ebro valley, and Southwest France/Pyrenees. Some recent publications explain the problems linked with the debate about the origins and expansion of blade technology (that includes pressure knapping) and trapezes along the Western Mediterranean (Binder et al. 2012). Basically, across the different regions of this whole area we do not have a uniform degree of information regarding radiocarbon dates, nor the same standard of care in the selection of samples. The isolated dates in charcoal from Uzzo (Sicily) and Latronico (Southern Italy) offer ancient radiocarbon dates. In the North of Africa (mainly Gafsa and Tebessa regions, Tunisia and Algeria) similar dates are available but with standard deviations well over the 100 limit we imposed. We also find dates focused on the first half of the seventh millennium coming from charcoal samples in Iberia and Southern France.

When we select only short-life samples (with anthropic marks) the information is less than scarce, and obviously not conclusive considering the number of dates compared. An East/Western gradient with two possible foci (Eastern Neolithic or Upper Capsian in the North of Africa) has been indicated (Binder et al. 2012). Additionally, the discussion about the origins of blade technology (using pressure technology) and trapeze complexes demands more dates that would allow us to explore the mechanisms and the social networks involved. For the time being current radiocarbon dataset of Mesolithic assemblages do not permit us to offer more details on this relevant question.

Taking into account these considerations, the interval 6600–6400 cal BC reflects in the maps the first important growth signal related to radiocarbon date densities in the particular area covering Eastern Iberia and Northern Italy. After that a variable density of dates is visible in the further intervals until 6000 cal BC, focused in the same spatial framework. Other regions like Portugal present a weak signal clearly distorted by the number of dates from shells not included in the maps. As we have mentioned, from the middle of the seventh millennium cal BC, estuarine and coastal areas of Portugal show distinctive concentrations of Mesolithic populations in open air sites that include necropolis areas, implying a certain stability in the residential pattern (Carvalho 2009). The strongest Mesolithic density of dates occurs at the 6200–6000 cal BC interval along the Eastern Mediterranean coast and the Ebro valley, highlighting at the same time some meaningful empty territories like Central Italy, the Catalonia region, the Meseta area and the Northwest of Iberia. At that point (6200–6000 cal BC) it is still possible to observe a weak signal of the Neolithic arrival in Southern Italy.

In our view, there is no general impact related to the so-called ‘8.2 calBP event’ apparent in any of the maps. As has been indicated in other works focused on Iberia (Bernabeu et al. 2014), this event does not seem to have had a wide impact as far as Mesolithic settlement is concerned, and the zoom region by region requires more detailed information in order to better evaluate some of the effects pointed out elsewhere (González-Sampériz et al. 2009).

The 6000–5800 cal BC interval includes the first clear signal of the Neolithic arrival to Southern Italy. At the same time, we can glimpse a reduction in intensity of the Mesolithic density of dates in the remaining territories. Despite several external features that have been referred to explain this variation, it seems interesting to introduce two main consequences suggested by the map. In the first place, it is evident that different indications of Mesolithic settlement exist in some areas, as we can see to a large extent in Iberia, at the time of the arrival of the Neolithic way of life to Southern Italy. Secondly, radiocarbon densities seem weaker and reflect some changes in site distribution. Are these changes a real reflection of the final Mesolithic settlement patterns? And in this case, is it possible to link them with the pristine Neolithic wave?

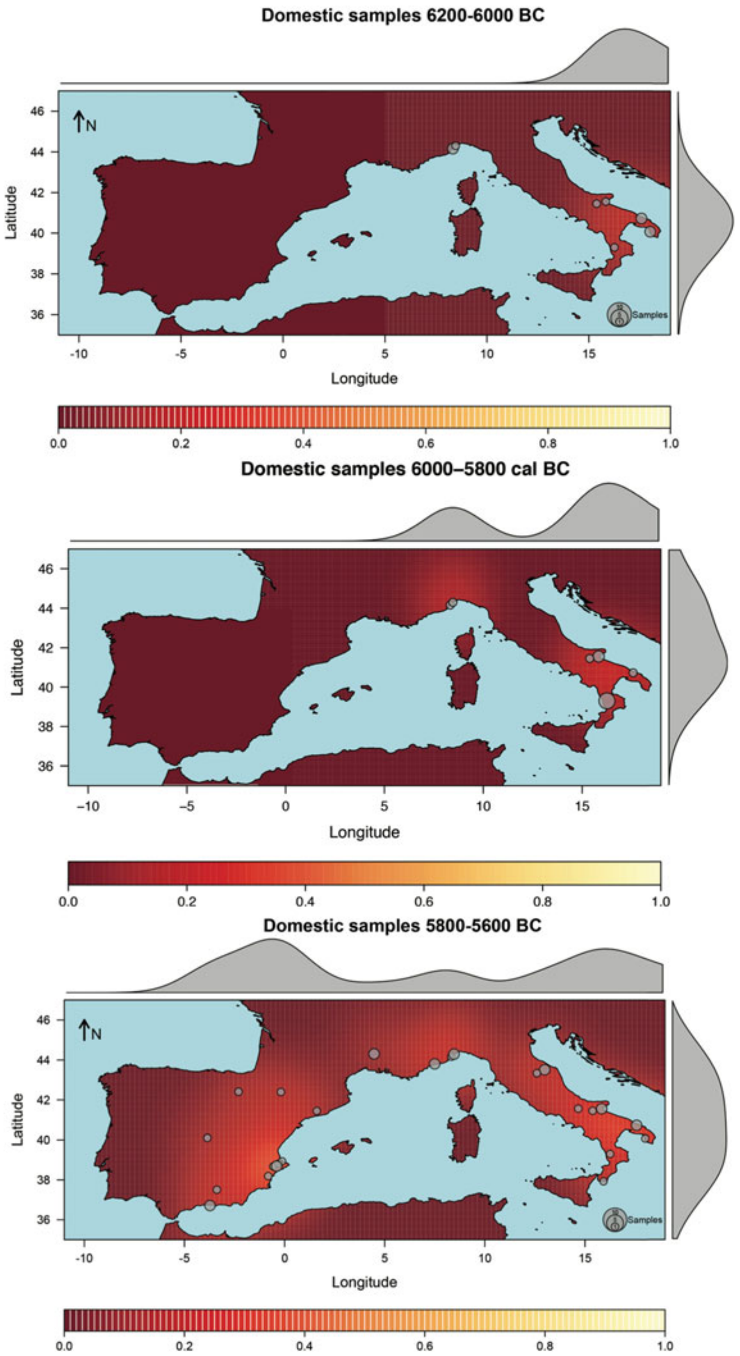
The following map (Fig. 4.6) allows us to introduce the debate about the Neolithic expansion mechanism. As we can see, the 5800–5600 cal BC interval shows an impressive increment in radiocarbon date densities. Italy as a whole, including the Sicily and Sardinia islands, reflects an indubitable impact of Neolithisation as shown by a complete set of dated domestic short-life samples.

It is possible to follow the advance in radiocarbon densities along the Mediterranean coast of Southern France and the settlement of Catalonia (with very low densities of occupation if any in the centuries before the Neolithic arrival). Emphasising this progress, Fig. 4.7 and Table 4.2 reflect domestic radiocarbon dates published for the entire area. In Iberia the rise indicated during the 5800–5600 cal BC interval also shows a simultaneous westerly gradient reaching as far as Eastern Andalusia. This growth in radiocarbon densities affects the territories along the Mediterranean coast and the Ebro corridor. In fact, at the Peña Larga site in the Upper Ebro valley there is a domestic bone dated back to this period (Beta242783: 6720, 40, 5670–5572 cal BC 1 sigma: Fernández Eraso 2012). This fast spread of the Neolithic along the Ebro corridor (Fano et al. 2014) contrasts with the existence of Mesolithic settlements at least until the middle of the sixth millennium in the Navarra territories, and even more so in the Cantabrian region, where it is possible to observe a much longer persistence on into the fifth millennium cal BC.

We are not able to discuss here the possible North African route pointed out by some authors (Isern et al. 2014), because we intentionally omitted the minimal African data. We hope there will be an increasing number of radiocarbon dates as new sites are excavated and made public on both sides of the Gibraltar strait. A closer look at Portugal in the 5800–5600 cal BC interval shows that the rhythm of date densities observed there is entirely related to Mesolithic sites (Fig. 4.8).

The next maps present the rapid movement of radiocarbon date densities towards the Western territories. The first dated domestic remains are largely situated in the 5600–5400 cal BC interval (Caldeirao: OxA1035: 6330, 80, 5463–5218 cal BC 1 sigma, Zilhão 2003). During this interval and the following the persistence of Mesolithic groups is evident in most of the northern Iberian Atlantic coast and in Portugal, but is not well defined in other Iberian areas (such as the Eastern region), known up to this time as hunter-gatherer territories, at least according to current archaeological knowledge (see Juan Cabanilles and Martí in this volume).

Consequently, we can conclude that the analyses carried out reflect a clear increase in radiocarbon densities coincident with the spread of food production economies throughout the Western Mediterranean area. This rise covers territories uninhabited prior to the arrival of agricultural and shepherding practices moving through the Mediterranean corridor (Zilhão 2001). The speediness of the process contradicts a progressive adoption by indigenous groups, as has been pointed out in other European regions (Woodbridge et al. 2012). Alternatively, the role of local



Domestic samples 6200-6000 BC

Domestic samples 6000–5800 cal BC

Domestic samples 5800-5600 BC

Fig. 4.7 Number of radiocarbon dates on domestic specimens by site (6200–5600 cal BP)

Table 4.2 Early Neolithic 14C on domesticates (SD < 100) in Western Mediterranean used in this work

Site	Country	Lab number	BP	SD	Material	Species	Ref
Abri de Pendimoun	France	Ly 5340	6490	75	Seed/fruit	Cereal	1
Abri de Pendimoun	France	Ly 5339	6320	95	Seed/fruit	Cereal	1
Abri de Pendimoun	France	LTL8005A	6599	45	Seed/fruit	Cereal	1
Abri de Pendimoun	France	LTL8006A	6649	45	Seed/fruit	Cereal	1
Abri de Pendimoun	France	GrA29403	6725	45	Seed/fruit	Cereal	1
Abri de Pendimoun	France	GrA29528	6650	45	Seed/fruit	Cereal	1
Aspres del Paradis	France	GRA 16273	6030	40	Bone	Ovis	2
Baume d’Oullins	France	AA 53291	6233	64	Bone	*Capra hircus*	3
Baume d’Oullins	France	AA 53294	6233	64	Bone	*Capra hircus*	3
Baume d’Oullins	France	AA 53292	6210	69	Bone	*Capra hircus*	3
Baume d’Oullins	France	AA 53296	6191	63	Bone	*Capra hircus*	3
Baume d’Oullins	France	AA 53293	6168	63	Bone	*Capra hircus*	3
Baume d’Oullins	France	ETH 27972	6510	60	Bone	Bos	4
Baume d’Oullins	France	ETH 27974	6250	60	Bone	Bos	4
Font des Pigeons	France	beta267434	6250	40	Seed/fruit	Cerealia	5
Mourre de la Barque	France	ETH 27980	6285	65	Bone	Bos	6
Mourre de la Barque	France	ETH 27979	6225	60	Bone	Bos	6
Mourre de la Barque	France	ETH 27978	6165	65	Bone	Bos	6
Mourre de la Barque	France	ETH 27981	6065	65	Bone	Bos	6
Arene Candide	Italy	Beta 110,542	6830	40	Seed/fruit	Cereal	7
Coppa Nevigata	Italy	OxA 1474	6850	80	Seed/fruit	Cereal	8
Coppa Nevigata	Italy	OxA 1475	6880	90	Seed/fruit	Cereal	8
Favella	Italy	LTL202A	6956	75	Seed/fruit	Cereal	9
Favella	Italy	Beta165482	6940	40	Seed/fruit	Cereal	9
Favella	Italy	LTL203A	6890	50	Seed/fruit	Cereal	9
Favella	Italy	LTL204A	6793	40	Seed/fruit	Cereal	9
Grotta Sant Angelo	Italy	Gif6724	6890	70	Seed/fruit	Cereal	8

(continued)

Table 4.2 (continued)

Site	Country	Lab number	BP	SD	Material	Species	Ref
Grotta Sant Angelo	Italy	Gif6722	6530	70	Seed/ fruit	Cereal	8
Monte Maulo	Italy	OxA 651	6540	80	Bone	*Cow radius*	10
Monte Maulo	Italy	OxA 652	6280	70	Bone	*Cow scapula*	10
Monte Maulo	Italy	OxA 653	6210	70	Bone	*Cow* Bone	10
Portonovo	Italy	LTL12777A	6555	45	Seed/ fruit	Cereal	11
Rippa Tetta	Italy	Beta47808	6890	60	Seed/ fruit	*Hordeum vulgare*	7
San Marco	Italy	OxA 1853	6430	80	Seed/ fruit	Cereal	12
San Marco	Italy	Oxa 1851	6270	70	Seed/ fruit	Cereal	13
San Marco	Italy	Oxa 1854	6120	90	Seed/ fruit	Cereal	13
Sebastiano di Perti	Italy	GrA25715	6760	45	Seed/ fruit	*Hordeum vulgare*	7
Torre Sabea	Italy	LJ1448	6860	45	Seed/ fruit	Cereal	8
Umbro	Italy	OxA23120	6526	34	Seed/ fruit	Cereal	14
Umbro	Italy	OxA23118	6484	33	Seed/ fruit	*Hordeum vulgare*	14
Umbro	Italy	OxA23119	6452	35	Seed/ fruit	Cereal	14
Umbro	Italy	OxA23121	6448	30	Seed/ fruit	Cereal	14
Umbro	Italy	OxA23122	6432	33	Seed/ fruit	Cereal	14
Umbro	Italy	OxA23117	6425	35	Seed/ fruit	*Hordeum vulgare*	14
Caldeirao	Portugal	OxA1035	6330	80	Bone	Ovis	13
Caldeirao	Portugal	OxA1034	6230	80	Bone	Ovis	13
Carrascal	Portugal	Beta276401	6280	40	Bone	*Bos taurus*	15
Carrascal	Portugal	Beta296582	6200	40	Bone	Ovis/capra	15
Vale Boi	Portugal	OxA13445	6042	34	Bone	Ovis/capra	16
Vale Boi	Portugal	Wk17030	6036	39	Bone	Ovis/capra	16
Abric de la Falguera	Spain	Beta142289	6510	80	Seed/ fruit	*Triticum monococcum*	17
Arenaza	Spain	OxA7157	6040	75	Bone	*Bos taurus*	16
Can Sadurní	Spain	OxA15488	6421	34	Seed/ fruit	Cereal	18
Can Sadurní	Spain	OxA15489	6391	34	Seed/ fruit	Cereal	18
Can Sadurní	Spain	OxA15491	6375	34	Seed/ fruit	Cereal	18
Can Sadurní	Spain	UBAR760	6405	50	Seed/ fruit	Cereal	18

(continued)

Table 4.2 (continued)

Site	Country	Lab number	BP	SD	Material	Species	Ref
Cariguela	Spain	Col1560	6350	32	Bone	Ovis	19
Cariguela	Spain	Col1564	6316	39	Bone	Ovis	19
Cariguela	Spain	Col1565	6749	39	Bone	Bos	19
Cariguela	Spain	Col1566	6482	39	Bone	Ovis/capra	19
Cariguela	Spain	Col1567	6225	39	Bone	Ovis	19
Casa Montero	Spain	Beta295152	6200	40	Bone	Ovis	8
Chaves	Spain	GrA38022	6580	35	Bone	Ovis	18
Chaves	Spain	UCIAMS66317	6470	25	Bone	Ovis	18
Cova Colomera	Spain	Beta240551	6150	40	Seed/fruit	*Triticum aestivum*	16
Cova d'en Pardo	Spain	Beta231877	6240	40	Bone	Ovis/capra	18
Cova d'en Pardo	Spain	Beta231879	6610	40	Bone	Ovis/capra	18
Cova de l'Or	Spain	UCIAMS66316	6475	25	Bone	Ovis	20
Cova de l'Or	Spain	Beta298124	6275	70	Seed/fruit	Cereal	20
Cova de l'Or	Spain	Beta298125	6340	40	Seed/fruit	Cereal	20
Cova de l'Or	Spain	Beta298126	6200	40	Seed/fruit	Cereal	20
Cova de l'Or	Spain	H1754/1208	6290	40	Seed/fruit	Cereal	20
Cova de l'Or	Spain	OxA10191	6275	70	Seed/fruit	Cereal	20
Cova de l'Or	Spain	OxA10192	6310	70	Seed/fruit	Cereal	20
Cova de la Sarsa	Spain	OxA236022	6389	33	Bone	*Bos taurus*	21
Cova de la Sarsa	Spain	OxA236025	6399	35	Bone	*Bos taurus*	21
Cova de la Sarsa	Spain	OxA26076	6506	32	Bone	*Ovis aries*	21
Cova de la Sarsa	Spain	OxA26075	6420	32	Bone	*Ovis aries*	21
Cova de les Cendres	Spain	Beta107405	6280	80	Bone	Ovis	18
Cova de les Cendres	Spain	Beta239377	6510	40	Bone	Ovis	18
Cova de les Cendres	Spain	Beta142228	6340	70	Seed/fruit	*Hordeum vulgare*	18
Cova de les Cendres	Spain	GifA101360	6490	90	Seed/fruit	*Triticum dicoccum*	18
Cueva de los Mármoles	Spain	Beta313470	6100	40	Seed/fruit	*Triticum dicoccum*	22
Cueva de los Mármoles	Spain	Beta313471	6250	40	Seed/fruit	*Triticum dicoccum*	22
Cueva de los Mármoles	Spain	Beta313472	6180	40	Seed/fruit	*Triticum dicoccum*	22
Cueva de los Mármoles	Spain	Beta313473	6180	30	Seed/fruit	*Triticum dicoccum*	22
Cueva de los Mármoles	Spain	Wk25171	6198	31	Seed/fruit	*Hordeum vulgare*	22

(continued)

Table 4.2 (continued)

Site	Country	Lab number	BP	SD	Material	Species	Ref
Cueva de los Murciélagos Z	Spain	beta313476	6110	40	Seed/ fruit	*Triticum dicoccum*	22
Cueva de los Murciélagos Z	Spain	Beta313477	6140	40	Seed/ fruit	*Triticum dicoccum*	22
Cueva de los Murciélagos Z	Spain	Beta316509	6200	40	Seed/ fruit	*Hordeum vulgare*	22
Cueva de los Murciélagos Z	Spain	GrN6169	6150	45	Seed/ fruit	Cereal	8
Cueva de los Murciélagos Z	Spain	GrN6639	6025	45	Seed/ fruit	Cereal	8
Cueva de los Murciélagos Z	Spain	OxA15646	6184	35	Seed/ fruit	Cereal	22
Cueva de los Murciélagos Z	Spain	OxA15647	6192	35	Seed/ fruit	*Hordeum vulgare*	22
Cueva de los Murciélagos Z	Spain	OxA15648	6199	36	Seed/ fruit	*Hordeum vulgare*	22
Cueva de los Murciélagos Z	Spain	OxA15649	6056	35	Seed/ fruit	*Hordeum vulgare*	22
Cueva de los Murciélagos Z	Spain	OxA15650	6170	37	Seed/ fruit	*Hordeum vulgare*	22
Cueva de Nerja	Spain	Beta131577	6590	40	Bone	Ovis	23
Cueva de Nerja	Spain	OxA26079	6207	32	Bone	Ovis	23
Cueva de Nerja	Spain	OxA26080	6196	31	Bone	Ovis	23
Cueva de Nerja	Spain	OxA26081	6219	33	Bone	Ovis	23
Cueva de Nerja	Spain	OxA26082	6214	35	Bone	Ovis	23
Cueva de Nerja	Spain	OxA26083	6252	33	Bone	Ovis	23
Cueva de Nerja	Spain	OxA26084	6254	33	Bone	Ovis	23
Cueva de Nerja	Spain	OxA26086	6466	33	Bone	Ovis	23
Cueva del Toro	Spain	Beta-341132	6150	30	Seed/ fruit	*Triticum aestivum*	24
Cueva del Toro	Spain	Beta341131	6110	30	Seed/ fruit	*Hordeum vulgare*	24
Cueva Font Major	Spain	Beta317705	6310	40	Bone	Ovis/capra	25
El Barranquet	Spain	Beta221431	6510	50	Bone	Ovis	18
El Mirador	Spain	Beta197384	6070	50	Seed/ fruit	Triticum	26
El Mirador	Spain	Beta208132	6090	40	Seed/ fruit	Triticum	26
El Mirador	Spain	Beta208133	6110	40	Seed/ fruit	*Triticum aestivum d.*	26
El Mirador	Spain	Beta208134	6300	50	Seed/ fruit	*Triticum dicoccum*	26
El Mirador	Spain	Beta220914	6080	40	Seed/ fruit	Triticum	26
Hostal Guadalupe	Spain	Wk25167	6249	30	Bone	Ovis/capra	3

(continued)

Table 4.2 (continued)

Site	Country	Lab number	BP	SD	Material	Species	Ref
Hostal Guadalupe	Spain	Ua34136	6190	50	Seed/ fruit	Cereal	3
Hostal Guadalupe	Spain	Wk25168	6197	35	Seed/ fruit	Cereal	3
La Draga	Spain	OxA20231	6163	31	Seed/ fruit	Cereal	16
La Draga	Spain	Oxa20232	6121	33	Seed/ fruit	Cereal	16
La Draga	Spain	OxA20233	6179	33	Seed/ fruit	Cereal	16
La Draga	Spain	Oxa20234	6127	33	Seed/ fruit	Cereal	16
La Draga	Spain	OxA20235	6143	33	Seed/ fruit	Cereal	16
La Lampara	Spain	UtC13346	6280	50	Seed/ fruit	*Triticum monococcum*	16
La Paleta	Spain	Beta223092	6660	60	Seed/ fruit	Cerealia	8
La Revilla del Campo	Spain	KIA21353	6156	33	Bone	Ovis/capra	16
La Revilla del Campo	Spain	KIA21354	6177	31	Bone	Ovis/capra	16
La Revilla del Campo	Spain	KIA21356	6355	30	Bone	Ovis/capra	16
La Revilla del Campo	Spain	UtC13269	6250	50	Seed/ fruit	Cereal	16
La Revilla del Campo	Spain	UtC13294	6240	50	Seed/ fruit	Cereal	16
La Revilla del Campo	Spain	UtC13295	6250	50	Seed/ fruit	Cereal	16
La Revilla del Campo	Spain	UtC13347	6313	48	Seed/ fruit	Cereal	16
La Revilla del Campo	Spain	UtC13348	6120	60	Seed/ fruit	Cereal	16
La Revilla del Campo	Spain	UtC13350	6210	60	Seed/ fruit	Cereal	16
Les Guixeres	Spain	OxA26068	6655	45	Bone	*Ovis aries*	27
Les Guixeres	Spain	OxA26069	6458	38	Bone	*Ovis aries*	27
Los Castillejos	Spain	Ua36203	6115	40	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua36208	6120	40	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua36209	6085	45	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua36210	6100	45	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua36212	6240	45	Seed/ fruit	Cereal	8

(continued)

Table 4.2 (continued)

Site	Country	Lab number	BP	SD	Material	Species	Ref
Los Castillejos	Spain	Ua36213	6120	40	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua36214	6260	45	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua36215	6310	45	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua37834	6090	40	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua37835	6155	45	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua37837	6065	50	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua37838	6095	45	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua37839	6130	50	Seed/ fruit	Cereal	8
Los Castillejos	Spain	Ua37844	6140	45	Seed/ fruit	Cereal	8
Mas d'Is	Spain	Beta331019	6140	30	Bone	*Bos taurus*	28
Mas d'Is	Spain	Beta331018	6030	30	Bone	*Bos taurus*	28
Mas d'Is	Spain	Beta162092	6600	50	Seed/ fruit	Cereal	29
Mas d'Is	Spain	Beta166727	6600	50	Seed/ fruit	Cereal	29
Peña Larga	Spain	Beta242783	6720	40	Bone	Ovis/capra	18
Roca Chica	Spain	Wk25162	6234	30	Bone	Ovis/capra	3
Roca Chica	Spain	Wk27462	6234	30	Bone	Ovis	3
Roca Chica	Spain	Ua34135	6265	60	Seed/ fruit	Cereal	3
Roca Chica	Spain	Wk25172	6185	30	Seed/ fruit	Cereal	3
Toll	Spain	OxA26070	6425	35	Bone	Ovis/capra	3
Toll	Spain	OxA26071	6390	34	Bone	Ovis/capra	3
Ventana	Spain	Beta166232	6350	40	Bone	Ovis	16

Reference numbers, *1*: Binder and Sénépart (2010), *2*: Manen et al. (2001), *3*: Cortés et al. (2012), *4*: Van Willigen et al. (2009), *5*: Perrin (2013), *6*: Van Willigen et al. (2009), *7*: Cruz Berrocal (2012), *8*: Fiorentino et al. (2013), *9*: Tiné (2009), *10*: Barker (1995), *11*: Conati Barbaro (2013), *12*: Pinhasi et al. (2005), *13*: Zilhão (2001), *14*: Bova Marina Archaeological Project (2011), *15*: Cardoso (2011), *16*: Rojo et al. (2012), *17*: García Puchol et al. (2009), *18*: Jover and García Atienzar (2014), *19*: Medved (2013), *20*: Badal et al. (2012), *21*: García Borja et al. (2012), *22*: Peña Chocarro et al. (2013), *23*: Aura et al. (2013), *24*: Camalich and Martín Socas (2013), *25*: Cebrià et al. (2014), *26*: Vergès et al. (2008), *27*: Oms et al. (2014), *28*: Bernabeu et al. (2014), *29*: Bernabeu (2006)

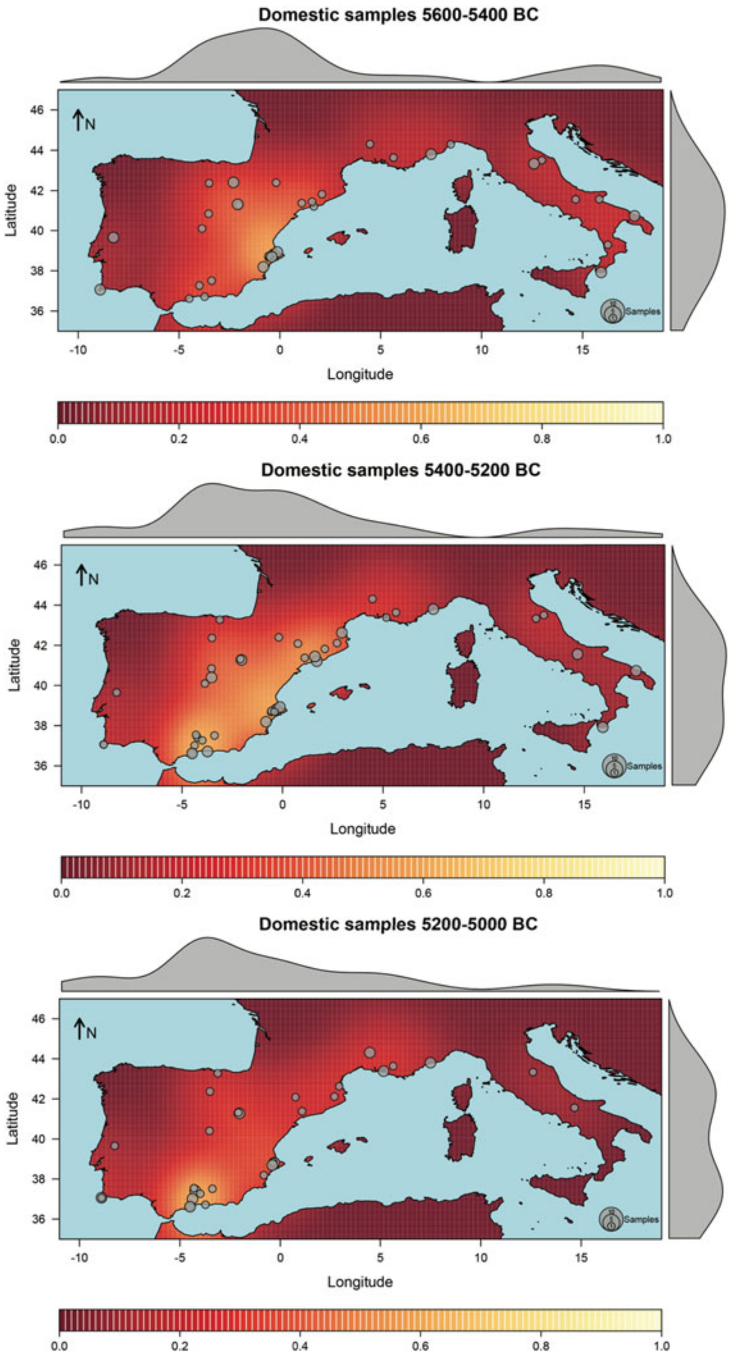


Fig. 4.8 Number of radiocarbon dates on domestic specimens by site (5600–5000 cal BP)

hunter-gatherers has long been discussed (Jordan and Zvelebil 2009; Zvelebil 2000, 2004, 2005). A mixed model that takes into account the important impact of a demic component in many parts of the entire area studied seems at the moment the more robust hypothesis.

4.6 Conclusion

In our concluding remarks we would like to strengthen some of the points stated in the text, and to deal with some of the main flaws. Our main interest is to show how the agricultural way of life (Neolithic) arrives in the Western Mediterranean regions. To do so, we have used the number of radiocarbon dates as a population proxy, based on the premise that the implementation of food production techniques serves as a trigger for demographic growth (Shennan 2012).

The few data available for most of the seventh millennium seem to reflect research preferences rather than the actual population, which would explain why in both the Bay of Biscay and the Gulf of Lyons there are some strong signals around the mid-millennium that expand towards the Gulf of Valencia and proceed along the Ebro valley. The total number of sites—and dates—is small and stable during the second half of the seventh millennium (Fig. 4.3). The research preferences referred to are the introduction of pressure blade technology and trapeze complexes in Southern France and Eastern Spain. In several areas of the Iberian Peninsula there are quite a few late Mesolithic excavated sites, mainly in the east (Valencian region), the Ebro valley and the Atlantic coast of Portugal.

Data seem to corroborate that after the arrival of the Neolithic to Southern Italy at the end of the seventh millennium cal BC, it spread rapidly to the rest of the Apennine Peninsula but also to the Tyrrhenian islands, confirming the prominent role of sea-faring in the Neolithic expansion. It should be noted that the much-debated '8.2 event' does not register any significance in our analysis.

If the number of dates and sites increases through much of the sixth millennium, it is also clear that there is a westerly gradient that reaches its maximum by 5200 cal BC when most of the Iberian Peninsula was already settled by Neolithic groups. However, we should highlight that most of the Cantabrian coast was still a hunter-gatherer territory and would continue to be so for centuries. The increment in radiocarbon dates in that area could be explained by the fact that most of the research focus has been placed on investigating whether these late Cantabrian hunter-gatherers were 'neolithised' at a moment simultaneous with the conspicuous presence of Asturian shell-middens (Fano et al. 2014).

In general terms, the 200-year pulses shown in our maps are in perfect agreement with the pioneer model proposed by J. Zilhão (2001). By 5600 cal BC, the agricultural way of life had extended to Sicily, the Venetian Gulf, the Ligurian Sea, the Gulf of Valencia and Southern Portugal. Two hundred years later the inland wave reached most of the Northern Meseta, the Alps, the Rhône valley and was extending from Lisbon through the Tagus Valley, bypassing part of Andalusia and Northwestern Iberia. By 5200 cal BC, it seems that a new expansion focus, in the Malaga coast, was joining the northern and Portuguese waves, thus constituting the moment of maximum Neolithic expansion. Thereafter the total numbers of both sites and dates decline rapidly, but that period lies beyond the scope of our current paper.

To sum up, we can conclude that even if radiocarbon dates are an optimal proxy for approaching demographic developments, it is also clear that research preferences could cloud the whole picture, especially when total numbers decrease. Other approaches, like differentiating hunter-gatherer from agricultural sites, have proved to be a difficult task without being familiar with the archaeological record in each area, and without taking an ‘a priori’ position favouring a particular interpretation. Another issue that should be explored in the future is that to what extent the Neolithic demographic growth has an influence on nearby hunter-gatherers, which could contribute to explaining why in some areas there seems to be demographic growth among the late hunter-gatherers once they are exposed to the agricultural way of life of their neighbours.

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Chapter 5
Alternative Stories of Agricultural Origins: The Neolithic Spread in the Iberian Peninsula

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5.1 Modeling the Neolithic Spread in Europe: An Iberian Perspective

The emergence of agriculture is one of the most important changes in the history of humanity due to its economic and social implications and its importance in the formation of modern human societies. The belief that the Neolithic in Europe resulted from the migration of agricultural societies originating in the Near East has been raised since the 1920s (Childe 1925; Clark 1965; Ammerman and Cavalli-Sforza 1984). Today's consensus on the origins of domestic plants and animals is based on studies conducted on DNA on domestic species (Bonfiglio et al. 2012; Larson and Burger 2014) and the observation of the absence of wild ancestors of the first Neolithic plants and animals in Europe (Colledge and Conolly 2001).

Although most of the current evidence favors immigrant farmers as the ultimate source of agriculture, this debate is far from settled. The archaeological evidence, unfortunately, is far from conclusive. Debate about these processes has often focused on the respective importance of indigenous Mesolithic groups and Neolithic pioneers and the mechanism of the spread. As more archaeological research into the spread of agriculture in Europe is conducted, the consensus shifts, and new routes and methods of spread for the arrival of agriculture are proposed. Regrettably, the excavation of more sites and the analysis of more samples for radiocarbon dates has finite utility when addressing complex, large-scale prehistoric events.

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Furthermore, the dates, pottery styles, lithic styles, and rock art are evidence best applied to local contexts and may not accurately reflect the large-scale and complex processes often proposed for the spread of agriculture. It is in this large-scale context that formal modeling offers a more objective and rigorous approach to evaluating the narrative models posed by archaeologists (Zilhão 1993, 2001; Zvelebil 2000; Bernabeu 2006; Martí 2008; Díaz del Río 2011) for the dispersal of food-producing economies across this region.[1] Most of these have been formal mathematical models (Fort 2009), the most prevalent being mathematical representation of an advancing wave front, generally focusing on some version of reaction-diffusion equations (Vander Linden 2011, 40) and few of these studies have included significant numbers of radiocarbon dates from the Iberian peninsula.

The first and most influential of such work was framed by Ammerman and Cavalli-Sforza (1984). Their work was based on an adaption of Fisher's reaction-diffusion model applied to the expansion of agricultural groups by implementing a constant population pressure (logistic growth) as a driving force, referred to as demic expansion. They evaluated this model for the demic diffusion of agriculture across different areas of the western Eurasia (1984, 134–135) by comparing the timing for the initial arrival of agriculture predicted by their model with then-available radiocarbon dates from the archaeological record (from 53 sites). They showed that the predictions of their model and observed dates for Neolithic sites were strongly correlated ($R = 0.8$) for an expansion rate of around 1 km/year ($c = 1.0 \pm 0.2$ km/year). Ammerman and Cavalli-Sforza's results also suggested a southeast-northwest gradient for the spread of Agriculture across Europe supporting the theory of a near eastern origin for the Neolithic promulgated by Clark in 1965. In this pioneering work, only two radiocarbon dates from the Iberian Peninsula, were used, each calculated from the average of then-available dates for Cova de l'Or (Alicante Province) and Cueva de los Murciélagos (Cordoba Province) in Spain.

In the past 15 years, the availability of inexpensive, high-speed computer processing and a greatly expanded radiocarbon database has led to a number of studies to revisit the empirical comparisons and demic diffusion models of Ammerman and Cavalli-Sforza. We briefly review some of the most notable of these recent studies. Gkiasta et al. (2003) undertook a spatial analysis of 510 radiocarbon dates for initial Neolithic sites (almost ten times the number available to Ammerman and Cavalli-Sforza's original study) and calculated an expansion rate for the first farmers of around 1.3 km/year across all of western Eurasia. They also examined summed probability curves for radiocarbon dates within subregions of the total area. The authors point out that a combination of approaches to examine large-scale (continental) development with small-scale (country) processes should be conducted to establish the quality of the radiocarbon information. Their study uses 39 radiometric dates, from 21 archaeological sites, from the Iberian Peninsula.

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[1] We will focus on the major studies that compare the results with the archaeological record. For a state of the art around the computer simulation applied to the movement of people see Steele (2009).

Pinhasi et al. (2005) simulated the spread of agriculture across western Eurasia with a demic diffusion model like that of Ammerman and Cavalli-Sforza. Yet instead of a single point of origin (Jericho in the original work), they calculated diffusion models from 30 different points of origin in Southwest Asia. They compared these 30 models with 735 Neolithic radiocarbon dates, obtaining correlation coefficients similar to those of Ammerman and Cavalli-Sforza ($0.77 \leq R \leq 0.83$) with expansion rates for the Neolithic across Europe ranging from 0.6 to 1.3 km/year. Although their total radiocarbon database was larger than that of Gkiasta et al. (2003), they used only 13 radiocarbon dates, from 13 archaeological sites, from the Iberian peninsula.

Studies by K. Davison and her team (Davison et al. 2006, 2007, 2009a, 2009b) are noteworthy for their investigation of the role of waterways in the expansion of the Neolithic. Like prior examples, they rely on reaction-diffusion equations as a basis for their model of Neolithic spread, but vary the rate of spread to reflect the potential for longer-distance "leapfrog" movement facilitated by waterways. They calculate an average Neolithic expansion across Europe of around 1 km/year, in line with other diffusion models. However, these authors estimate that the speed of the advancing front in the Rhine-Danube corridor was in the range 4–6 km/year, while in the Mediterranean coastal regions it increased to 10–20 km/year (Davison et al. 2009b, 204). They compared the results of their model with a database of 478 radiocarbon dates, but used only five radiocarbon dates from the Iberian peninsula.

Similar to the approach of Gkiasta et al. (2003), Bocquet-Appel et al. (2009) used geospatial interpolation (*kriging* in this case) to estimate the expansion rate of the Neolithic from an even larger radiocarbon database (3027 radiocarbon dates from 940 sites). They divided western Eurasia into a grid of 35 × 35 km resolution, and assigned each grid cell a date resulting from the average of the two earliest Neolithic sites in the cell. The authors contend that agricultural expansion was renewed at least ten times throughout Europe (Bocquet-Appel et al. 2009, 811–813), and consequently the spread of the Neolithic is characterized by periods of punctuated rapid movement and stasis. This aligns with proposals outlined previously by Bogucki (1996) for the LBK Neolithic and, more recently, by Guilaine (2001) in the "arrhythmic" model for the Mediterranean Neolithic. Because the radiocarbon database used in this study has not been published, we cannot assess the dates used from the Iberian Peninsula.

As was the case in the models explored by Davison and colleagues, Fort et al. (2012) also emphasize the potential importance of water travel in the spread of farming across western Eurasia (e.g., Dawson 2014). They simulated the spread of the Neolithic using a computational cellular automata, in which the region was divided into 50 × 50 km grid cells and virtual farming populations spread from grid cell to grid cell. They investigated the effects of homogeneous and heterogeneous environments (especially natural barriers and the possibility of maritime travel). The authors found that their simulations produced results that correlated well with the archaeological data when farmers were allowed to cross the ocean at distances of up to 150 km. A total of 919 radiocarbon dates were used in this study, including 40 dates, associated with 39 sites, from the Iberian Peninsula.

Finally, the most recent Neolithic simulation work has been reported by Silva and Steele (2014). The authors combine regression analysis and genetic algorithms to explore the parameter space of multiple geospatial models of Neolithic expansion derived from radiometric dates gathered by Pinhasi et al. (2005). Because they used the Pinhasi radiocarbon database, their model incorporated only 13 sites from the Iberian Peninsula.

5.2 The Neolithic Spread Model

Over the past decade, computational modeling has become a common and sophisticated tool in the archaeological analytic toolbox (Costopoulous 2010; Barton 2013; Lake 2014, 2015). Yet it is worth providing a sketch of the theoretical background and methodological foundations inherent to computational modeling. Commonly referred to as agent-based modeling (ABM), the use of computers to support social theory is not actually a new concept (Hägerstrand 1965). In archaeological research, the first widely recognized application of agent-based modeling was the Artificial Anasazi model (Dean et al. 1999; Axtell et al. 2002). Artificial Anasazi investigated the population dynamics of Anasazi agricultural groups in Long House Valley, Arizona (the American Southwest), by integrating hydrological and environmental data with household agents and compared the population curve produced from the simulation to one suggested from archaeological research. In a similar fashion agent-based models are often developed today to account for data in existing datasets. Instead, we have opted for a first principles approach. As aptly described by Bankes et al. (2002), computational modeling well-suited to evaluating hypothesis and comparing those hypothesis to existing datasets (see also Grimm et al. 2005). The formalization of conceptual models that computational modeling forces upon researchers is a valuable exercise which ultimately improves our theories and furthers discourse (Miller and Page 2007).

Here, we discuss results of using ABM to study the dynamics of agricultural dispersals across the Iberian Peninsula. The Iberian Peninsula is an especially important area for the study of neolithization by virtue of the rapid spread of agriculture, supported by archaeological evidence, and a large number of new radiocarbon dates—orders of magnitude more than used in prior modeling exercises discussed above. We developed ABM computational protocols for three well-discussed modes of agricultural spread in the Neolithic and implemented each in the Netlogo modeling platform (Wilensky 1999). In addition to being a widely used and freely available platform, Netlogo allows us to import and use georeferenced datasets within the modeling environment, including radiocarbon dates and ecological information (discussed below). Our model takes the form of a spatially explicit cellular automata in a gridded landscape, in which agriculture can spread from one or more starting locales to adjacent or nearby grid cells on the basis of conditional rules described below for each spreading mode.

As with the prior modeling work discussed above, we compared the results of modeling different spread routines to empirical archaeological data and statistically assess the degree to which each of the spread scenarios fit with the archaeological data. While this approach does not produce definitive conclusions about the past, it allows us to differentiate among scenarios that were more and less likely to have produced the empirical archaeological record, and allows for an exploration of the parameters necessary to achieve results that best fit our archaeological datasets.

The three modes of Neolithic dispersal tested in our model are neighborhood spread, leapfrog spread, and the Ideal Despotic Distribution (IDD) model from human behavioral ecology (Fretwell and Lucas 1970; Kennett et al. 2006; McClure et al. 2006; Whitehead and Hope 1991). With the neighborhood model, agriculture spreads to all adjacent cells without agriculture, akin to the wave of advance model (Fischer 1937; Ammerman and Cavalli-Sforza 1984). For the leapfrog spread model, farmers colonize a cell chosen randomly from cells without agriculture within a given radius. Although leapfrog spread seems analogous to the maritime spread model proposed by Zilhão (2001), this spread routine can spread inland as well as along the coast. IDD is based upon ideas advanced by McClure et al. (2006) and Shennan (2008) in which agriculture spreads to the best available land within a given radius based on ecological factors and the density of farmers (cells with agriculture).

Although the mechanics of agricultural dispersals are obviously of importance to the spread of the Neolithic on the Iberian Peninsula, most researchers would also point to environmental factors as a crucial factor when looking at the speed and direction of the spread of agriculture. This is seen in some of the modeling summarized above. With this in mind, we situate our modeling in a digital landscape that approximates prehistoric environmental conditions. The simulations are run on a gridded landscape at a resolution of 5 × 5 km, with an ecological index value assigned to each cell ranging from zero (unsuitable for cereal agriculture) to ten (highly favorable). The ecological index is a quantitative estimate of how favorable the conditions in each cell would have been for wheat farming, representing a composite of slope, spring rainfall, spring maximum temperature, and minimum temperature in March (Bernabeu et al. 2015). The ecological index can be used when deciding on a destination cell to which agriculture will spread. For instance, with the leapfrog spread mode, agriculture would spread to a randomly chosen patch within a given radius of the initiating patch that does not yet have agriculture and has an ecological index above a given threshold. Rather than assume that agriculture spread southwest from a point in northeastern Iberia (a common assumption to most theoretical models), the model also allows us to test different start points, or even have a combination of different simultaneous start points. Agriculture then spreads from cell to cell according to the spreading mode rules and does not necessarily expand in any particular direction.

Our Neolithic spread model allows us to change the spread procedure, the importance of environmental conditions to the spread, the maximum distance for each spread episode, the effect of population in the IDD spread mechanism and the starting location—thus a large number of distinct parameter combinations are possible. Because of the stochasticity resulting from the selection of cells to which agriculture spreads, every simulation run has the potential to produce slightly different results, even with the same starting parameter values. To determine how many runs of a scenario are necessary to adequately capture the resulting variation in results, we conducted sensitivity experiments. These tests indicated that variation in simulation results begins to stabilize at ten repetitions, and that repeating a simulation scenario 20 times produced results statistically equivalent to repeating it 100 times. To be on the safe side, we repeated each scenario 50 times. Additional details of the model and the model code itself are published in the CoMSES Net Computational Model Library at https://www.openabm.org/model/4447/.

Each combination of modeling parameters produces a scenario that can be considered as a hypothesis about the mechanisms, point of origin, rate, and direction for the spread of agricultural economies across the Iberian Peninsula. We compare the results of each of these model hypotheses against the radiocarbon dataset to quantitatively evaluate its fit with the empirical archaeological record. The time (in model cycles) needed for the agriculture to reach each dated Neolithic site in the peninsula is recorded for each simulation run. The correlation coefficient, R, is calculated for the relationship between model arrival times for agriculture and radiocarbon dates for sites each simulation run. R values for all simulation runs were saved and analyzed for each spread mode. Since we are comparing simulation timesteps which increase through time, with radiocarbon dates which decrease in value from oldest to youngest, negative correlations indicate good results.

In previous experiments we have discussed the comparison of modeling results from different starting points and the effects of spread mechanisms (Bernabeu et al. 2015). Earlier experiments also suggested the importance of ecological factors and leapfrog movement for the spread of agriculture in Iberia. In the following set of experiments we take a different tact and use the modeling environment to examine the ability of radiocarbon datasets to evaluate modeling results, an issue especially relevant to all efforts to model the spread of farming across Europe. The number and availability of radiocarbon dates has increased dramatically in the past two decades, and new dates as well as their locations can improve the development and evaluation of models for the spread of the Neolithic. Here we examine the effects of using radiocarbon data from different sources on the correlations between model results and empirical data to encourage the careful examination of radiocarbon samples since collecting accurate chronological information is a key first step.

5.3 Archaeological Background for Computational Modeling

Since the 1990s, the Iberian Peninsula has witnessed a significant increase in the number of radiocarbon dates associated with the Neolithic transition. However, as we have previously discussed this new radiometric information has not yet been utilized in computer models for Neolithic dispersals at continental scales. Moreover, on numerous occasions the use of archaeological dates has not been subjected to a critical review of the sample and its archaeological context, even though this kind of quality assessment has the potential to strongly influence results. Several recent studies have revealed contextual issues that can affect the interpretation of radiocarbon dates in the archaeological record, such as the effect of old wood and mixing of carbon from different sources in bulk radiocarbon samples (Zilhão 1993, 2011; Bernabeu 2006).

Fortunately, recent modeling work at a regional level has begun to correct this problem (Isern et al. 2014; Bernabeu et al. 2015). Here we use the recently expanded radiocarbon database for the Iberian Peninsula and assess the impacts of radiocarbon sample context on modeling results.

5.3.1 The Radiocarbon Iberian Dataset

For the radiocarbon dataset, we selected sites representing the earliest Neolithic in the Iberian Peninsula. Because farming economies did not arrive at all places in the peninsula simultaneously, this includes sites within a chronological range that covers the initial Neolithic expansion across Iberia. For all but the extreme northwest of the Peninsula, we used all sites with dates between 6720 ± 40 BP (the currently known oldest directly dated domestic remains, from the site of Peña Larga in the Ebro Valley (Fernández Eraso 2011)) and 5500 BP (encompassing the initial Neolithic dates from western Europe, as well as Iberia). We also included sites located in the extreme north of the Peninsula that with dates earlier than 5000 BP (e.g., Kobaderra, Marizulo, Peña Oviedo and Pico Ramos) because the Neolithic arrived there later than rest of Iberia. With the exception of dates from three human burial contexts, described in more detail below, the radiocarbon dataset only includes dates clearly associated with archaeological remains of domestic taxa (plant or animal). We do not consider dates from uncertain depositional contexts or from sites that contain ceramics but otherwise lack evidence of domesticates. Radiocarbon dates derived from burnt bones are also excluded because of the associated problems as shown by Olsen et al. (2008). Finally, we do not use dates with a standard deviation greater than 100 since as the calibration range increases so does background noise which does not allow for the observation of concrete phenomena. This issue has previously been tested in a methodological example (Rojo et al. 2006).

5.3.1.1 Dates from Human Burial Contexts

Three burial contexts are sufficiently associated with initial Neolithic occupation, although indirectly, that we also include them here.

Plaça de la Vila de Madrid (Beta-18271): This date comes from a Neolithic burial located in a pit found in the context of a Roman excavation (Pou et al. 2010). The date has associated lithics and the Neolithic level doesn't have domestic remains, but we have decided to include this radiocarbon date since the site of la Caserna de Sant Pau del Camp is located 500 meters away and domestic remains and structures for the storage of grain have been documented there (Molist et al. 2008).

Los Canes (AA-5788): This date comes from organic material inside of a ceramic vessel associated with a burial located in SU7. We have included this date but recognize that *"the relationship between technology and the new economic concept is far from clear."* (Cubas and Fano 2011, 78).

Peña Oviedo (GrN-18782): This date comes from a fireplace associated with the construction phase of a dolmen (Peña Oviedo I). While human bones were not recovered due to the thinness of the soil, it seems clear that it is the earliest date for the Neolithic occupation in the Picos de Europa (Diez Castillo 1997, 2007).

5.3.1.2 Context of Radiocarbon Samples

We have classified all dates according to the material dated to better assess the quality of their age estimates. This classification identifies three kinds of dates:

1. Samples dating the remains of domestic plants or animals
2. Samples from short-lived taxa, such as animal bones and shrubs, clearly associated with evidence for domestication
3. Samples dating remains of wood charcoal (i.e., long-lived taxa) that are clearly associated with levels in which the use of domesticates is evident

Using these selection criteria, our radiocarbon dataset consists of dates on 53 long-lived taxa, 39 short-lived and 42 domestic (direct-evidence), for a total of 134 dates from 115 archaeological sites. These are detailed in Table 5.1 and Fig. 5.1. The dataset used here represents the most complete compilation of radiocarbon dates for the initial appearance of the Neolithic in the Iberian Peninsula available at the time of our experiments. As with some (but not all) of the formal models used for representing Neolithic dispersals and discussed above, it is important to make clear that we use the radiocarbon dataset for the evaluation of our models for the spread of agriculture, not for the creation of these models.

Overall, directly dated remains of domestic plants and animals should provide the most reliable information for evaluating formal models of Neolithic dispersals. We note, however, that questions have been raised about potential problems of

Table 5.1 Radiocarbon dates used in this work. L = Long-taxa, S = Short-taxa, D = Domestic taxa

Site	Code lab	Type	Sample	Level	BP	SD	cal BP (smean)	References
Abauntz	GrN21010	L	Charcoal	II r	5820	40	6618	Utrilla (1982)
Abric de la Falguera	Beta142289	D	Seed (Tritucum)	UE 2051b	6510	80	7407	Bernabeu (2006)
Almonda	OxA9288	S	Bone (Stag)	I	6445	45	7373	Zilhão (2001)
Alto de Rodilla	CSIC1967	S	Bone (Human)	II	6171	55	7082	García-Martínez (2014)
Arenaza	OxA7157	D	Bone (Bos taurus)	IC2	6040	75	6889	Arias et al. (1999)
Atxoste	GrA9789	S	Bone	III b	6220	60	7132	Utrilla et al. (1998)
Barruecos	Beta171124	L	Charcoal	UE 134	6080	40	6944	Cerrillo (2005)
Benàmer	CNA539	S	Pollen	II	6575	50	7491	Torregrosa et al. (2011)
Buraco da Pala	GrN19104	L	Charcoal	IV lower	5860	30	6692	Zilhão (2000)
Ca l'Estrada	Poz10391	S	Bone (human)	SF501	5740	40	6555	Gibaja and Carvalho (2010)
Cabranosa	Sac1321	S	Shell (Mytilus)	fireplace	6550	70	7490	Zilhão (2001)
Caldeirao	OxA1035	D	Bone (Ovis)	NA II	6330	80	7290	Zilhão (2001)
Can Bellsola	AA19187	L	Charcoal	TBC4	6250	80	7144	Martí and Pou (1998)
Can Roqueta	**	S	Bone	CRII-173	6400	50	7345	Oliva et al. (2008)
Can Sadurní	OxA15488	D	Seed (Tritucum)	Layer 18	6421	34	7367	Blasco et al. (2011)
Can Xammar	**	L	Charcoal	UE 3025–3026	6270	40	7210	Martí and Pou (1998)
Canaleja 2	AA78257	L	Charcoal	UE 4	6203	44	7091	Gibaja and Carvalho (2010)
Cariguela	Pta9163	S	Bone (Human)	CIV II 2	6260	20	7207	Fernández et al. (2007)
Carrascal	Beta276401	D	Bone (Bos taurus)	NA level	6280	40	7214	Cardoso (2011)
Casa da Moura	TO953	S	Bone (Human)	Ia	5990	60	6820	Zilhão (2000)
Casa Montero	Beta295152	D	Bone (Ovis)	Pit 15,267	6200	40	7093	Capote (2013)

(continued)

Table 5.1 (continued)

Site	Code lab	Type	Sample	Level	BP	SD	cal BP (smean)	References
Casa Montero	Beta232890	L	Charcoal (Quercus ilex)	Pit 16,309	6500	40	7398	Capote (2013)
Castelo Belinho	Sac2031	S	Bone (Human)	Structure 1	5790	70	6582	Gibaja and Carvalho (2010)
Cerro Virtud	OxA6714	S	Bone (Human)	Level 6 (B3.30)	6030	55	6870	Montero and Ruiz (1999)
Chaves	GrA38022	D	Bone (Ovis)	Ib	6580	35	7468	Baldellou (2011)
Chaves	GrN12685	L	Charcoal	Ib	6770	70	7625	Utrilla and Baldellou (1985)
Cingle del Mas Cremat	Beta232340	S	Seed (Sorbus sp.)	IIIb	6020	50	6862	Vizcaíno (2010)
Codella	Beta221900	D	Bone (Ovis)	Not specified	5720	60	6530	http://radon.ufg.uni-kiel.de/samples/3616
Costamar	OxA23578	D	Bone (Bos)	UE 40102	5995	38	6838	Flors (2009)
Cova Avellaner	UBAR109	S	Bone (Human)	3A	5830	100	6622	Bosch and Tarrús (1990)
Cova Colomera	OxA-23634	D	Seed (Tritucum)	CE 14	6170	30	7086	Oms et al. (2013)
Cova de la Sarsa	OxA26076	D	Bone (Ovis)	–	6506	32	7402	García Borja et al. (2012b)
Cova de les Cendres	Beta239377	D	Bone (Ovis)	H19	6510	40	7406	Bernabeu and Molina (2009)
Cova de les Cendres	Beta75220	L	Charcoal	EVII	6730	80	7590	Bernabeu and Molina (2009)
Cova de l'Or	UCIAMS66316	D	Bone (Ovis)	VI a	6475	25	7381	Martí (2011)
Cova del Petrolí	Beta172871	L	Charcoal	VII	6020	40	6852	Aguilella (2002)
Cova del Toll	OxA26070	D	Bone (Ovis)	IIb	6425	35	7368	Cebrià et al. (2014)
Cova del Vidre	Beta58934	L	Charcoal	II	6189	90	7107	Bosch (1993)
Cova d'en Pardo	Beta231879	D	Bone (Ovis-Capra)	VIII	6610	40	7513	Soler et al. (2011)
Cova Font Major	Beta317705	D	Bone (Ovis)	Ig	6310	40	7224	Cebrià et al. (2014)
Cova Foradada	Beta248524	D	Bone (Ovis)	Ic	6200	40	7093	Cebrià et al. (2011)

Cova Fosca	CSIC357	L	Charcoal	IA	7210	70	8057	Olaria and Gusi (1988)
Cova Fosca d'Ebo	OxA26047	D	Bone (Ovis)	II z	6413	33	7364	García Borja et al. (2012a)
Cova Gran	Beta265982	S	Seed (acorn)	E9	6020	50	6862	Mora et al. (2011)
Cova Sant Martí	Beta166467	S	Bone (Human)	UE206	5740	40	6555	López and Torregrosa (2004)
Cueva Chica de Santiago	UGRA254	L	Charcoal	Not specified	6160	100	7044	Bernabeu (2006)
Cueva de la Dehesilla	UGRA259	L	Charcoal	Not specified	6260	100	7143	Acosta and Pellicer (1990)
Cueva de la Higuera	Beta166230	S	Bone	II	6250	60	7144	Jiménez Guijarro et al. (2008)
Cueva de los Mármoles	Wk25171	D	Seed (Hordeum)	N1 D2	6198	31	7094	Gibaja and Carvalho (2010)
Cueva de los Murciélagos (Albuñol)	CSIC1133	S	Charcoal (Stipa)	Not specified	6086	45	7013	Sánchez-Barriga et al. (1996)
Cueva de los Murciélagos (Zuheros)	GrN6639	D	Seed (Cereal sp.)	C	6025	45	6865	Acosta (1995)
Cueva de los Murciélagos (Zuheros)	GrN6926	L	Charcoal	Not specified	6295	45	7219	Muñoz Amilibia (1972)
Cueva de Nerja	Beta131577	D	Bone (Ovis)	IV	6590	40	7496	Jordá and Aura (2006)
Cueva del Gato	GrA22525	L	Charcoal	S1	6240	50	7141	Utrilla and Montes (2009)
Cueva del Hoyo de la Mina	Ua19444	L	Charcoal	IV (corte 6)	6190	65	7084	Baldomero (2005)
Cueva del Toro	GrN15443	L	Charcoal	IV	6320	70	7244	Socas et al. (2004)
Cueva Lóbrega	GrN16110	L	Charcoal	III lower	6220	100	7128	Barrios (2004)
El Barranquet	Beta221431	D	Bone (Ovis)	UE 79	6510	50	7406	Bernabeu et al. (2009)
El Cavet	Beta222342	L	Charcoal (Quercus sp.)	UE 2014	6620	60	7518	Oms and Morales (2008)
El Congosto	KIA27582	S	Bone (Human)	Not specified	6015	50	6860	Martín Bañón (2007)
El Mirador	Beta208134	D	Seed (Tritucum)	MIR 23	6300	50	7220	Vergés Bosch et al. (2008)
El Mirador	Beta197386	L	Charcoal	MIR 24	7060	40	7897	Vergés Bosch et al. (2008)
El Mirón	GX309010	D	Seed (Cereal sp.)	Trench 303.3	5550	40	6348	Peña-Chocarro et al. (2005)
El Mirón	GX25856	L	Charcoal	Trench 303.3	5790	90	6598	Peña-Chocarro et al. (2005)

(continued)

Table 5.1 (continued)

Site	Code lab	Type	Sample	Level	BP	SD	cal BP (smean)	References
El Tonto	Beta317251	D	Bone (Ovis)	---	6230	30	7138	Inedit (Diaz del Rio Personal com.)
Font de la Vena	UBAR61	L	Charcoal	Not specified	6190	100	7107	Cruells et al. (1992)
Font del Ros	AA16498	L	Charcoal	SN	6561	56	7489	López Morillas et al. (1996)
Fuente Celada	UGA75665	S	Bone (Human)	H62-UE622	6120	30	7048	Alameda et al. (2011)
Gruta do Correio-Mor	ICEN1099	L	Charcoal	fireplace	6350	60	7296	Gibaja and Carvalho (2010)
Gruta do Correio-Mor	Sac1717	S	Bone (Human)	Not specified	6330	60	7246	Gibaja and Carvalho (2010)
Hostal Guadalupe	Wk25167	D	Bone (Ovis-Capra)	Not specified	6249	30	7205	Cortés et al. (2012)
Hostal Guadalupe	Wk25169	S	Bone (Human)	Not specified	6298	30	7220	Cortés et al. (2012)
Huerto Raso	GrA21360	L	Charcoal	B	6310	60	7231	Montes et al. (2000)
Kobaederra	AA29110	D	Seed (Cereal sp.)	IV	5375	90	6150	Zapata (2002)
Kobaederra	UBAR470	L	Charcoal	IV	5630	100	6403	Arias et al. (1999)
La Dou	Beta221903	L	Charcoal	E1	5660	50	6426	http://radon.ufg.uni-kiel.de/samples/3821
La Draga	Beta278255	D	Bone (Ovis-Capra)	I	6270	40	7210	Bosch and Tarrús (2008)
La Draga	UBAR314	L	Charcoal (Quercus sp.)	II	6410	70	7353	Bosch et al. (2000)
La Lampara	UtC13346	D	Seed (Tritucum)	Structure 1	6280	50	7214	Rojo et al. (2008)
La Lampara	KIA16576	L	Charcoal (Pinus sp.)	Structure 9	7136	33	7961	Rojo et al. (2008)
La Lampara	KIA21347	S	Bone	Structure 18	6407	34	7360	Rojo et al. (2008)

La Paleta	Beta223091	D	Bone (Ovis)	Structure 175	5850	40	6685	Jiménez Guijarro et al. (2008)
La Paleta	Beta223092	D	Seed (Cerealia)	Structure 219	6660	60	7535	Jiménez Guijarro et al. (2008)
La Revilla del Campo	KIA21356	D	Bone (Ovis-Capra)	Structure 4	6355	30	7286	Rojo et al. (2008)
La Revilla del Campo	KIA13941	L	Charcoal	Structure 4	7165	37	7983	Rojo et al. (2008)
La Revilla del Campo	KIA21358	S	Bone	Structure 14	6365	36	7333	Rojo et al. (2008)
La Serreta	Beta280862	L	Charcoal (Arbustus u.)	E61-EU6106	6490	40	7384	Oms et al. (2014)
La Vaquera	GrN22931	L	Charcoal	UE 94	7050	70	7878	Estremera and López García (2003)
La Vaquera	GrA8241	S	Fruit (acorn)	UE 98	6080	70	6976	Estremera and López García (2003)
Las Torrazas	GrN18320	L	Charcoal	C	5570	60	6354	Utrilla and Baldellou (1996)
Les Guixeres	OxA26068	D	Bone (Ovis)	A	6655	45	7538	Oms et al. (2014)
Los Canes	AA5788	L	Charcoal	UE 7	5865	70	6674	Arias and Pérez (1995)
Los Cascajos	Ua24427	D	Seed (Cereal sp.)	Structure 516	6250	50	7145	García et al. (2011)
Los Cascajos	Ua24428	L	Charcoal (jun.sp)	Structure 551	6435	45	7371	García et al. (2011)
Los Castillejos	Ua36215	D	Seed (Cereal sp.)	I	6310	45	7223	Gibaja and Carvalho (2010)
Los Gitanos	AA29113	S	Bone	A3	5945	55	6764	Arias et al. (1999)
Los Husos I	Beta161182	S	Bone	XVI	6240	60	7141	Fernández Eraso and Barandiarán (2007)
Los Husos II	Beta221640	S	Bone	VII	6050	40	6878	Fernández Eraso (2011)
Marizulo	Ua-4818	S	Bone (Human)	I	5285	65	6067	Zapata (1995)
Mas d'Is	Beta162092	D	Seed (Hordeum)	House 2	6600	50	7500	Molina et al. (2011)
Molino de Arriba	KIA41450	S	Bone (Human)	UE 202	6120	30	7048	García-Martínez (2014)

(continued)

Table 5.1 (continued)

Site	Code lab	Type	Sample	Level	BP	SD	cal BP (smean)	References
Monte dos Remedios	Ua32670	L	Sediment	Not specified	5780	40	6577	Fábregas et al. (2007)
Novelda	Beta227572	L	Charcoal (Quercus sp.)	UE 101	6390	40	7342	García Atiénzar et al. (2006)
Paco Pons	GrA19295	L	Charcoal	II	6045	45	6876	Montes et al. (2000)
Padrao	ICEN873	S	Shell (Tapes)	fireplace	6570	70	7494	Zilhão (2000)
Padre Areso	GrN14599	L	Charcoal	II	5380	100	6150	Beguiristain (1979)
Parco	CSIC281	L	Charcoal	IV	6170	70	7072	Petit (1996)
Paternanbidea	GrA13673	L	Bone (Human)	Burial 1	6090	40	6948	García et al. (2011)
Pena d’Agua	Wk9214	L	Charcoal (Olea)	Layer Eb lower	6775	60	7626	Zilhão (2001)
Peña Larga	Beta242783	D	Bone (Ovis/ Capra)	IV	6720	40	7570	Fernández Eraso (2011)
Peña Oviedo	GrN18782	L	Charcoal	I	5195	25	5953	Diez Castillo (1997)
Pico Ramos	Ua3051	D	Seed (Hordeum)	IV	5370	40	6151	Zapata (1995)
Pla del Serador	Poz10422	L	Charcoal	E203	5810	40	6614	Martin et al. (2010)
Plansallosa	Beta74311	L	Charcoal	I	6180	60	7083	Bosch et al. (1998)
Plaça Vila de Madrid	Beta18271	S	Bone (Human)	Not specified	6440	40	7373	Pou et al. (2010)
Portalón	Beta197387	L	Charcoal	N9 north	7790	40	8566	Ortega et al. (2008)
Portalón	Beta222339	S	Bone	N9 north	6100	50	7021	Ortega et al. (2008)
Prazo	Ua20492	L	Charcoal	S1-UE 4	5735	50	6549	Lopez Sáez et al. (2006–2007)
Prazo	GrN26404	S	Charcoal (Arbustus u.)	SVII-UE 3	5630	25	6400	Lopez Sáez et al. (2006–2007)
Puyascada	CSIC384	L	Charcoal	II	5930	60	6758	Baldellou (1987)

Retamar	Beta90122	S	Shell	Fireplace 18	6780	80	7630	Ramos Muñoz (2002)
Riols I	GrN13976	L	Charcoal	A	6040	100	6944	Royo and Gómez (1992)
Roca Chica	Wk27462	D	Bone (Ovis)	Not specified	6234	30	7140	Cortés et al. (2012)
Sanavastre	UBAR574	L	Charcoal	E4	5780	60	6577	Mercadal et al. (2009)
Sant Pau del Camp	Beta236174	S	Bone	Trench 1	6290	50	7216	Molist et al. (2008)
Sao Pedro de Canaferrim	ICEN1152	L	Charcoal	UE 4	6070	60	6969	Zilhão (2000)
Senhora das Lapas	ICEN805	S	Bone (Human)	Layer 3	6100	70	7020	Zilhão (2000)
Serrat del Pont	Beta172521	S	Bone (Sus scrofa)	III	6470	40	7379	Alcalde et al. (2002)
Tossal de les Basses	Beta232484	D	Seed	UE34	5950	50	6787	Rosser and Fuentes (2007)
Valada do Mato	Beta153914	L	Charcoal	UE 7	6030	50	6869	Diniz (2011)
Vale Boi	OxA13445	D	Bone (Ovis-Capra)	C II	6042	34	6875	Carvalho (2008)
Vale Boi	Wk17842	S	Bone (wildlife)	C II	6095	40	7016	Carvalho (2008)
Vale Santo 1	Wk12139	S	Shell (Thais)	C I	6245	60	7143	Carvalho (2008)
Ventana	Beta166232	D	Bone (Ovis)	II lower	6350	40	7328	Jiménez Guijarro et al. (2008)

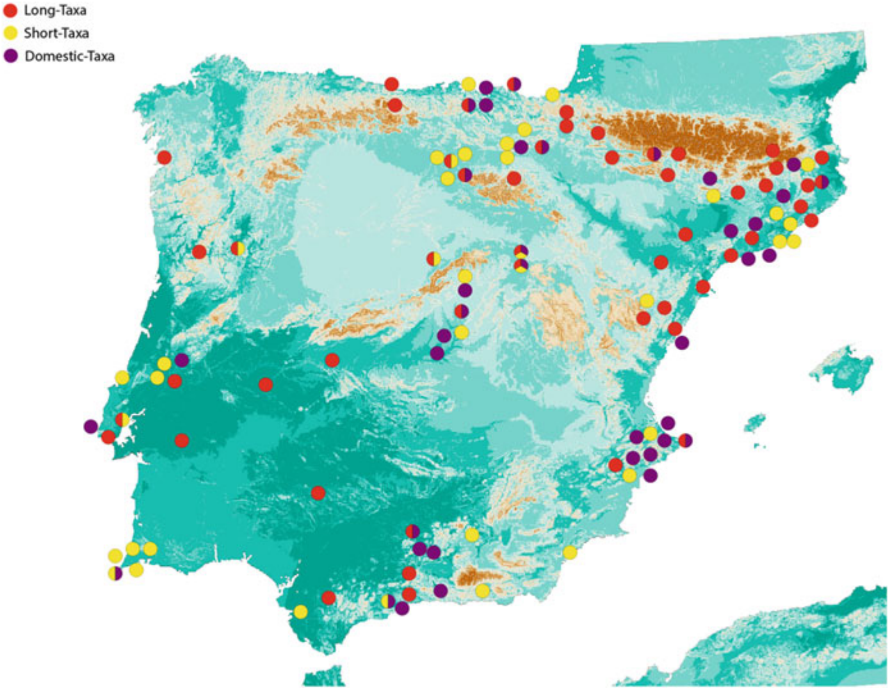

Fig. 5.1 Location of the sites used in this research

differentiating some bones of domestic ovicaprines from wild ones, specifically *Capra ibex* in the Iberian Peninsula (Zilhão 2011, 49). Ultimately, it may be necessary to resolve this with biomolecular methods, such as protein analysis, of samples prior to dating (Martins et al. 2015). Because such analyses are not yet widely available, we must rely on macroscopic analysis for the radiocarbon dataset used here. Moreover, dates on domestic taxa often are simply not available. In such cases, the next best would be dates on short-lived taxa from Neolithic sites with domestic taxa. But again, these are often not available, leaving dates on longer-lived woody taxa. On the other hand, a larger number of dates from more sites can provide a statistically better evaluation instrument for formal modeling of the spread of agriculture than a small number of sites. An important question we attempt to address here is whether a larger radiocarbon database that includes dates from short-lived or long-lived taxa can serve as well or better than a smaller dataset with more reliable radiocarbon dates.

5.4 Results

By comparing the results obtained in different simulations with various subsets of the data, we expect to be able to address the following questions: Is there any impact on the results depending on the type of radiocarbon sample used? And if so, what subset of the data produces better results? In this paper we use a fixed set of model parameters for each run and test five scenarios:

1. Neighborhood spreading mode with no consideration of the ecological suitability for cereal agriculture.
2. Neighborhood spreading mode with spreading only to cells in which the index for ecological suitability for cereal agriculture >3.
3. Leapfrog spreading mode with leap distance $=5$ and no consideration of the ecological suitability for cereal agriculture.
4. Leapfrog spread with leap distance $=5$ and suitability index for cereal agriculture >3.
5. IDD spreading mode with cost for previous agricultural occupation of a cell decreasing suitability for cereal agriculture by 5% for each time a cell is occupied.

We start the simulation from 17 different origin points located at the mouths of various rivers around the perimeter of the Iberian Peninsula and one point in the center as a null case (for details, see Bernabeu et al. 2015). Overall, this produced 340 scenarios (20 for each of the 17 starting points) for a total of 17.000 individual model runs.

Figure 5.2 shows two examples of regressions from two disparate model runs in order to illustrate poor and well-correlated results. The regression showing model results of neighborhood spread from the Rio Xúquer is a strong correlation ($R = -0.38$ and $p = 0.02$). The figure of a fitted regression of model runs using Madrid as a starting point and spreading via the neighborhood spread routine depicts a very poor correlation ($R = 0.07$ and $p = 0.67$). In this case, Madrid is used as a sort of null hypothesis since agriculture is found in the coastal regions of the Iberian Peninsula long before it is found in the interior near Madrid.

5.4.1 *Comparing Simulation Results Against Oldest Vs. Best Dates*

Our first experiment focuses on results from two subsets of the radiocarbon database, which we term *oldest* and *best*. The first concerns the oldest date (mean radiocarbon) of each site independently of the dated sample. The other *best* subset refers to the best available date for each site using the following criteria: (a) samples that dates domestic items directly if available; (b) if none are available, dates from short-lived taxa are selected; (c) if neither are available, we use dates from long-

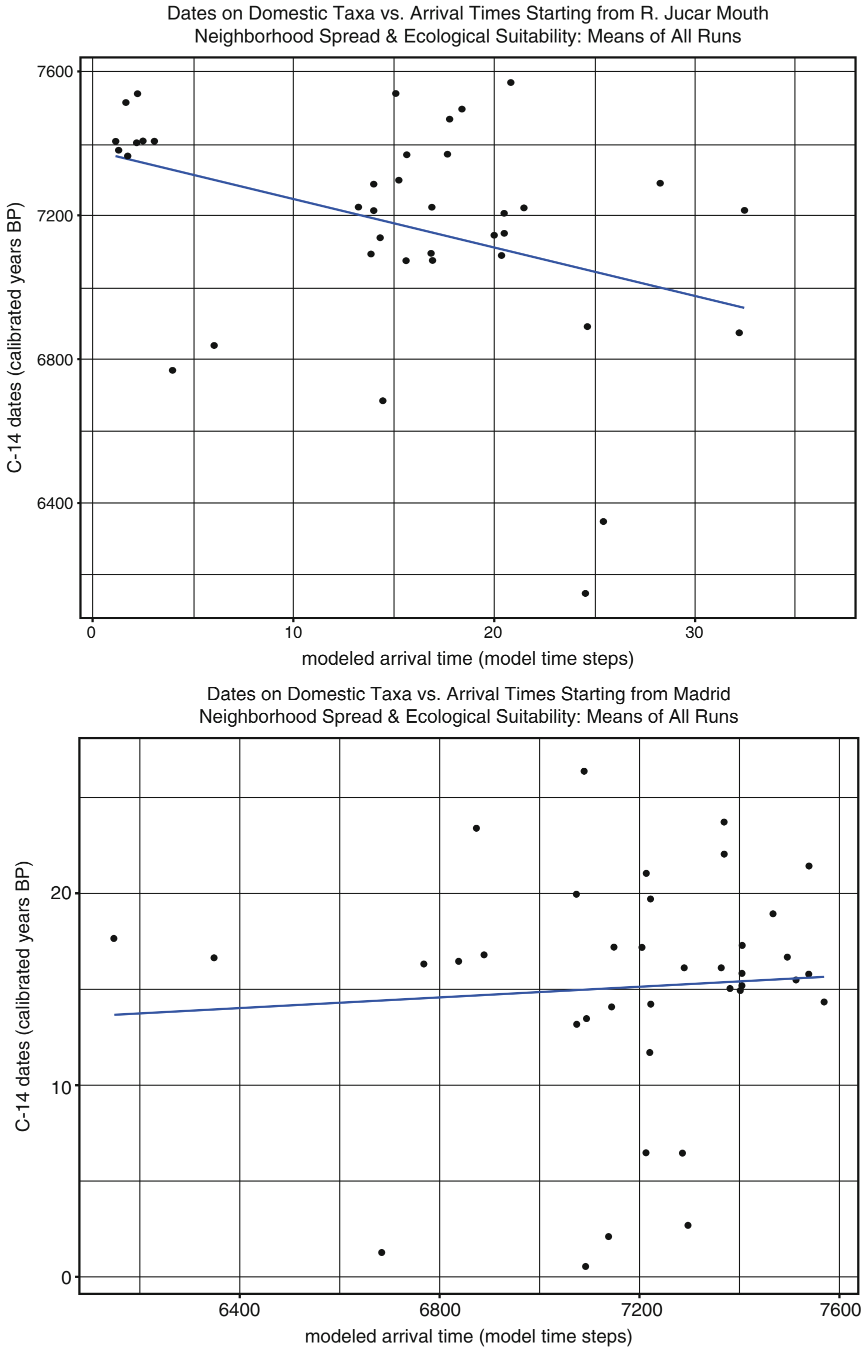

Fig. 5.2 Regression examples between radiocarbon dates and model time-arrival. (**a**) Origin point in East of Iberia. (**b**) Origin point in the center of Iberia

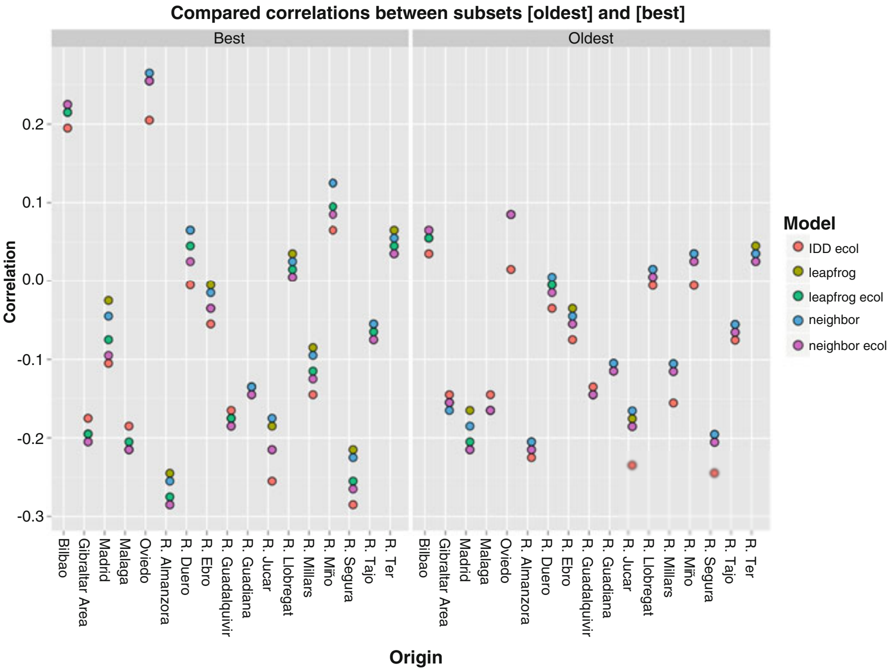

Fig. 5.3 Comparative results between subsets oldest and best

lived taxa. Both *best* and *oldest* dates include information from all the dated sites, and so represent equal-sized samples of dates. We calculate correlation coefficients between the modeled arrival agriculture and the radiocarbon date for each site; this process was conducted for each of the starting points and spread types.

The results of this experiment are shown in Fig. 5.3. The best correlation between model results and dated Neolithic sites occurred when the radiocarbon dataset was limited to the *best* subset, with $R = -0.283$ with origin point for modeled agricultural dispersals located at the mouth of the Segura river (southern Iberia). Of the 20 strongest correlations ($R = -0.283$ to -0.213), most (15) are associated with the *best* subset of the radiocarbon data. It is clear from this first experiment that different selection criteria from the sample of C14 dates can produce quite different results when used to evaluate formal models of Neolithic dispersals. Below, we examine these effects in more detail.

5.4.2 Comparing Results of Best Dates Versus Dates on Domestic + Short-Lived Taxa

Best dates include a mix of dates on domestic taxa, nondomestic short-lived taxa, and nondomestic long-lived taxa. A possibly more reliable, though smaller,

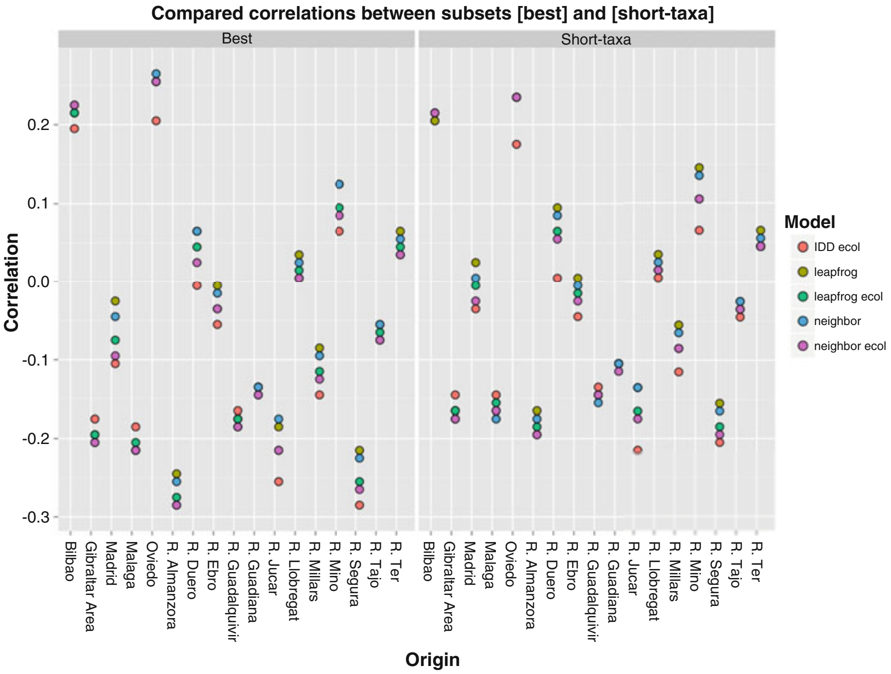

Fig. 5.4 Comparative results between subsets best and short-taxa

radiocarbon dataset is limited to only dates on domestic taxa and nondomestic short-lived taxa. These are combined in the *short-lived* dataset. The resulting model correlations with *best* vs. *short-lived* dates are shown in Fig. 5.4. If we look at the 20 strongest correlations, we see some unexpected results. The more "reliable" *short-lived* radiocarbon dataset generates correlation coefficients considerably worse than the larger, mixed *best* dates set. None of the 20 correlations generated using the *short-lived* dates are better than those from the same origin point using the *best* samples.

A possible reason that the *short-lived* dates set produced lower correlations than the *best* dates set is that includes dates made on shells (e.g., from Cabranosa, Padrao, Retamar, and Vale Santo) that could be affected by reserve effect problems. Previous work done in the north of the Iberian Peninsula focused on critically evaluating the dates made on shells and established the need to pre-calculate the value of the reserve effect in each local area (Rubinos et al. 1999, 154). This issue has been confirmed in subsequent work which emphasized that the reserve effect varies in space and time (Ascough et al. 2005) and that although the correction can be determined there remains considerable variation (Soares and Dias 2006).

To test this possibility, we selected the Rio Segura starting point for each of the five configurations and we removed those dates made on shells in the *short-lived* dates set. We used the Rio Segura because it produced the best correlation in previous experiments. The results of this experiment are shown in Table 5.2.

Table 5.2 Comparative results between short-taxa (A) and short-taxa without shells (B)

Starting point	Model	Correlation A	P. value A	Correlation B	P. value B
R. Segura	IDD ecol	−0.28307	0.0015	−0.28842	0.0147
	Leapfrog ecol	−0.25654	0.0041	−0.31335	0.0077
	Neighbor ecol	−0.26121	0.0035	−0.31348	0.0077
	Neighbor	−0.22414	0.0126	−0.30412	0.0099
	Leapfrog	−0.21843	0.0152	−0.30594	0.0094

Removing dates on shell form the *short-lived* dataset significantly improves the model results for all of the five scenarios. The most striking case is for scenario three, leapfrog spread mode without consideration of suitability for cereal cultivation, in which R improves from −0.21 to −0.30. These results indicate that the use of samples made on shells can be problematic when used to evaluate model results, and consequently we suggest the exclusion of these types of radiocarbon dates (see also Bernabeu et al. 2014).

5.4.3 Comparing Results of Short-Lived Date Set Vs. Dates on Domestic Taxa Only

In the last experiment we have compared the *short-lived* dates (i.e., combination of dates on domestic taxa plus short-lived nondomestic taxa) with the smaller group of dates from domestic taxa alone. The potential value of using only domestic radiocarbon dates for developing and evaluating formal models of Neolithic dispersals has been raised in other works (e.g., Bernabeu et al., 2015, García Puchol et al., *in this volume*). However, this places considerable limits on the number of dating samples available to use in this way.

Because it is clear from the previous experiments that starting points outside the Mediterranean littoral generated very low (or even reversed) correlations with all radiocarbon datasets, we used only those originating locales between the Gibraltar area and the Ter River. The results of this experiment are shown in Fig. 5.5. The best correlation was generated from a spread model originating at the mouth of the Jucar River and the domestic taxa-only radiocarbon dataset ($R = -0.395$). If we look at the 25 best correlations produced in this experiment, considerably better correlations were produced using the more reliable domestic taxa-only dates than the larger *short-lived* dataset, even without dates on shell. Of all 25 correlations that have a value of $R > -0.3$, 16 are derived from comparisons with the domestic taxa-only radiocarbon dates. Looked at in another way, only two of the nine starting points (Gibraltar and Malaga) display a higher correlation when compared with the *short-lived* dataset without dates on shell.

Across all the experiments, the results suggest that the quality of the radiocarbon sample used, not only the number of dates, needs to be considered when using a body of dates to evaluate the results of computational modeling of the spread of

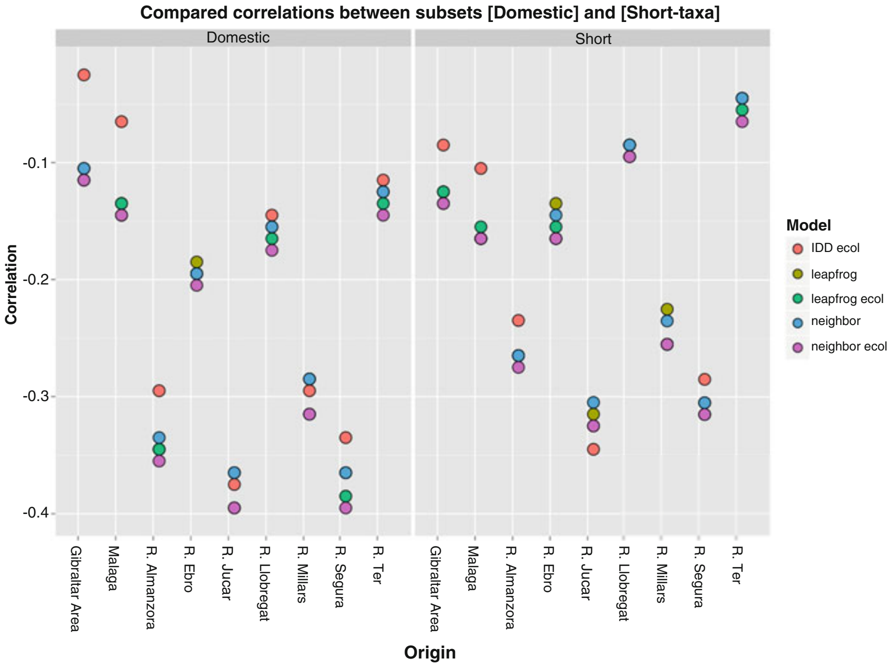

Fig. 5.5 Comparative results between subsets domestic and short-taxa

farming. The importance of using careful and rigorous criteria for the selection of radiocarbon dates noted previously (Bernabeu 2006, Zilhão 2011) is firmly reflected in the results of our modeling experiments.

5.5 Concluding Remarks

Our objective with this work was to illustrate the importance of methods and concepts derived complex adaptive systems (CAS) approaches in order to understand dynamic socio-ecological processes like the spread of agropastoral systems. We have showcased the utility of using ABMs to evaluate alternative hypothesis about the spread of the Neolithic using the Iberia peninsula as a specific case study. The radiocarbon dataset used for model evaluation and testing in this research is the most complete yet used for the Iberian peninsula—and there are yet more recently published radiometric dates which could not be used here but should be considered in future work, such as new analyses from Cueva de la Carigüela (Mevdev 2013), Balma Margineda, and Cova Bonica (Oms 2014).

The context of radiocarbon samples used strongly affected the outcome of model evaluation, and is of critical importance for any spatiotemporal analysis of Neolithic dispersals. We found that dating samples from domestic taxa are the most reliable way to evaluate our Neolithic spread model and by extension are likely the best data to use for understanding this prehistoric process, a point suggested previously by other scholars. Our results suggest the potential value of using a similarly filtered radiocarbon dataset for continental-scale models, although this would be difficult with currently available information (Gkiasta et al. 2003). The results from our modeling experiments offer concrete support for widely held assumptions about the direction for the spread of farming in the Iberian Peninsula in the most general sense. The Neolithic spread in Iberia is best explained by a progressive movement from east to west; the reverse assumption (west to east) yields poor correlation results.

As discussed above, this paper is a first attempt to understand a complex problem using a promising new approach and underscores the importance of carefully selecting the dates included in the evaluation of that problem. We have only begun to compare a limited set of hypotheses and our future research could introduce cultural variables like ceramics technology. By the same token, the environmental data we used is derived from modern data, and in the future we must introduce environmental data associated with middle Holocene (circa 8000–6000 BP). These results are preliminary, and additional experiments are currently being performed using new sets of radiocarbon dates and an enhanced environmental model.

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Part III

Landscape Interactions: Farming and Herding

Chapter 6
Neolithic Human Societies and Woodlands in the North-Western Mediterranean Region: Wood and Charcoal Analysis

Ernestina Badal García, Yolanda Carrión Marco, Lucie Chabal,
Isabel Figueiral, and Stéphanie Thiébault

6.1 Introduction

This overview of woodland history in the north-western Mediterranean region is based on charcoal analysis from sites occupied during the Mesolithic and the Neolithic. Charcoal analysis (also referred to as ‘Anthracology’) is a relatively recent palaeoenvironmental discipline, whose reliability lies on rigorous methodological principles mainly developed during the 1990s (Badal 1990a; Chabal 1997; Figueiral and Willcox 1999; Théry-Parisot 2001a; Théry-Parisot et al. 2010). The taxonomic identification of charcoal fragments and the diachronic variations of taxa frequencies provide an image of the local vegetal cover, exploited for firewood by human communities. Despite the unavoidable human filter, this gathering of firewood ends up providing accurate and reliable environmental information, as human communities exploited a large number of woody plants, probably all those available in the vicinity of their settlements.

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The technological and social innovations leading to the Neolithic emerged in the Near East expanding towards the west and spreading across Europe via two routes (Ammerman and Cavalli-Sforza 1984; Guilaine 2001; Zilhão 2001; Perrin and Binder 2014). The first Neolithic communities reaching the western Mediterranean region encountered a large diversity of situations in terms of ecology and human distribution. The global climatic changes had come to a halt by the end of the Boreal and the biogeographic configuration had stabilized. In short, climatic and environmental changes preceded the cultural and technological changes at the basis of the introduction of farming and animal husbandry in Western Europe. Minor climatic events (8.2 Ka, 7.8 Ka, 7.1 Ka) are repeatedly discussed but no clear conclusions are ever reached concerning their eventual impact on prehistoric societies (Magny 2004; Gronenborn 2009; Berger and Guilaine 2009; González-Sampériz et al. 2009; Bernabeu et al. 2014).

This chapter will focus on the Mediterranean areas of southern France, Spain and Portugal (Fig. 6.1, Table 6.1), where geography and climate generated a great diversity of landscapes and ecological situations, from the north to the south, from the coast to the interior (Ozenda 1975, Rivas-Martínez 1987).

During the Holocene, landscapes were both the result and the reflexion of the interaction between climate, geographic and social changes. Rising sea levels modifying coastal geography, climate warming leading to the spread of plant species, and from the Neolithic onwards, spontaneous forestry dynamics, demography, economy and technology are the main environmental agents in contention.

This does not imply that the technology used by the last hunter-fisher-gatherers was not capable of modifying the environment; however that of the Neolithic populations had a far greater capacity of changing the landscapes. These changes are clearly carried out by the first farmers, who created the 'rural landscape' and

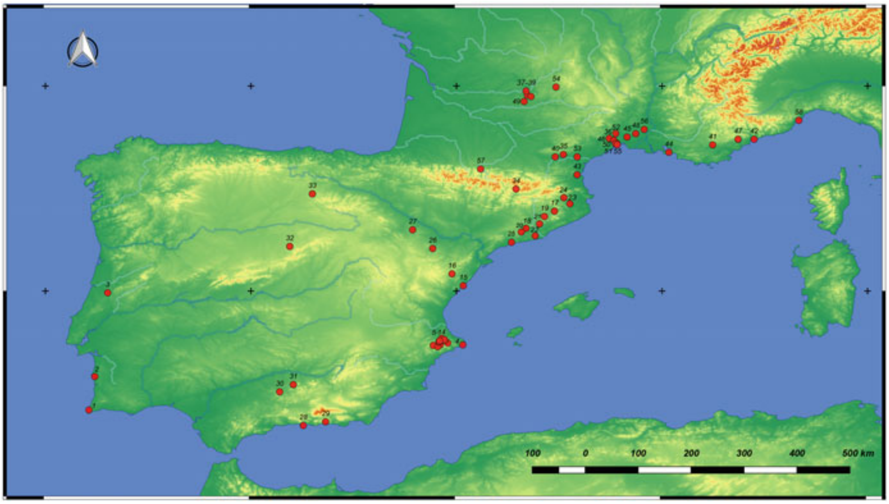


Fig. 6.1 Location of sites cited in the text. The reference numbers for sites are in Table 6.1

Table 6.1 Sites cited in the text (Portugal, Spain, Andorra, France and Italy)

Site reference in Fig. 6.1	Country	Site	Region/ community	District/ province	Town	Altitude (m)
1	Portugal	Castelejo	Algarve	–	Vila do Bispo	25
2	Portugal	Vale Pincel I	Alentejo	–	Sines	10
3	Portugal	Buraca Grande	Extremadura	–	Pombal	350
4	Spain	Cova de les Cendres	País Valenciano	Alicante	Teulada	45
5	Spain	Abric de la Falguera	País Valenciano	Alicante	Alcoi	860
6	Spain	Cova de l'Or	País Valenciano	Alicante	Beniarrés	650
7	Spain	Mas d'Is	País Valenciano	Alicante	Penáguila	610
8	Spain	Santa Maira	País Valenciano	Alicante	Famorca	650
9	Spain	Tossal de la Roca	País Valenciano	Alicante	Alcoi	691
10	Spain	La Sarga	País Valenciano	Alicante	Alcoi	895
11	Spain	Jovades	País Valenciano	Alicante	Cocentaina	400
12	Spain	Niuet	País Valenciano	Alicante	Alqueria d'Aznar	350
13	Spain	Cova de 'En Pardo	País Valenciano	Alicante	Planes	650
14	Spain	Benamer	País Valenciano	Alicante	Muro d'Alcoi	350
15	Spain	Torre la Sal	País Valenciano	Castellón	Oropesa	0
16	Spain	Cova Fosca	País Valenciano	Castellón	Ares del maestre	950
17	Spain	Cingle Vermell	Cataluña	Barcelona	Villanova de Sau	703
18	Spain	Abric Agut	Cataluña	Barcelona	Capellades	305
19	Spain	Balma del Gai	Cataluña	Barcelona	Bages	760
20	Spain	La Guineu	Cataluña	Barcelona	Font-Rubí	734
21	Spain	Cova del Frare	Cataluña	Barcelona	Matadepera	960
22	Spain	Can Sadurní	Cataluña	Barcelona	Begues	390
23	Spain	La Draga	Cataluña	Girona	Banyoles	163
24	Spain	Cova 120	Cataluña	Girona	Sales de Lierca	460
25	Spain	La Cativera	Cataluña	Tarragona	El Catllar	65
26	Spain	Los Baños de Ariño	Aragón	Zaragoza	Ariño	515

(continued)

Table 6.1 (continued)

Site reference in Fig. 6.1	Country	Site	Region/ community	District/ province	Town	Altitude (m)
27	Spain	Cabezo de la Cruz	Aragón	Zaragoza	La Muela	428
28	Spain	Cueva de Nerja	Andalucía	Málaga	Nerja	158
29	Spain	Cueva de los Murciélagos Albuñol	Andalucía	Granada	Albuñol	350
30	Spain	Cueva de los Murciélagos Zuheros	Andalucía	Córdoba	Zuheros	980
31	Spain	Polideportivo Martos	Andalucía	Jaén	Martos	725
32	Spain	La Vaquera	Meseta	Segovia	Torreiglesias	960
33	Spain	El Mirador	Meseta	Burgos	Ibeas de Juarros	1033
34	Andorra	Balma Margineda	–	–	Sant Julià de Lòria/Andorra la Vella	970
35	France	Abeurador	Languedoc-Roussillon	Hérault	Félines-Minervois	560
36	France	Boussargues	Languedoc-Roussillon	Hérault	Argelliers	256
37	France	Cuzoul de Gramat	Midi-Pyrénées	Lot	Gramat	330
38	France	Escabasses	Midi-Pyrénées	Lot	Thémines	320
39	France	Fieux	Midi-Pyrénées	Lot	Miers	250
40	France	Font Juvénal	Languedoc-Roussillon	Aude	Conques-sur-Orbiel	200
41	France	Fontbrégoua	Provence-Alpes-Côte d’Azur	Var	Salernes	400
42	France	Giribaldi	Provence-Alpes-Côte d’Azur	Alpes-Maritimes	Nice	70
43	France	L’Esperit	Languedoc-Roussillon	Pyrénées Orientales	Salses-le-Château	150
44	France	La Font des Pigeons	Provence-Alpes-Côte d’Azur	Bouches-du-Rhône	Châteauneuf-les-Martigues	50
45	France	Les Pins	Languedoc-Roussillon	Gard	Aubais	73
46	France	Les Vautes	Languedoc-Roussillon	Hérault	Saint-Gély-du-Fesc	140

(continued)

Table 6.1 (continued)

Site reference in Fig. 6.1	Country	Site	Region/ community	District/ province	Town	Altitude (m)
47	France	Lombard	Provence-Alpes-Côte d'Azur	Alpes-Maritimes	Saint-Vallier-de-Thiey	700
48	France	Moulin Villard II	Languedoc-Roussillon	Gard	Caissargues	27
49	France	Pégourié	Midi-Pyrénées	Lot	Caniac-du-Causse	370
50	France	Port Marianne-Espace Richter	Languedoc-Roussillon	Hérault	Montpellier	12–14
51	France	Richemont	Languedoc-Roussillon	Hérault	Montpellier	40
52	France	Rocher du Causse	Languedoc-Roussillon	Hérault	Claret	408
53	France	Sallèles d'Aude	Languedoc-Roussillon	Aude	Sallèles d'Aude	27
54	France	Sanglier	Midi-Pyrénées	Lot	Reilhac	580
55	France	St-Sauveur (pollen core)	Languedoc-Roussillon	Hérault	Lattes	4
56	France	Taï	Languedoc-Roussillon	Gard	Rémoulins	61
57	France	Troubat	Midi-Pyrénées	Hautes-Pyrénées	Troubat	541
58	Italy	Arene Candide	Ligurie	Province Savone	Finale Ligure	90

first managed their territories. Previous Mesolithic sites were few and far between especially in the Iberian Peninsula. Large empty spaces existed, for example, in Catalonia, in the Iberian Plateau, in the south of 'Pays Valenciano', Murcia and part of Andalucia (Juan-Cabanilles and Martí 2002; Martí and Juan-Cabanilles, 2014). In these areas, farming communities seem to have colonized practically empty territories. In southern France, the Neolithic settlements are also widely disconnected from previous occupations.

6.2 Iberian Peninsula

6.2.1 Early Holocene: Chronological, Regional and/or Cultural Differences

The worldwide climatic changes from the early Holocene (Preboreal and Boreal) led to changes in plant distribution and vegetation patterns. In the Iberian Peninsula, the changes between the Pleistocene and the beginning of the Holocene are recorded by charcoal analysis in sites occupied by Mesolithic communities.

Unfortunately, the information available is not uniform due to availability of sites and charcoal studies. Firstly, the early Mesolithic archaeological record is more consequent than the one of the Late Mesolithic. Secondly, some regions such as Catalonia, large stretches of eastern/southern Iberia and La Meseta lack late Mesolithic sites. Our third weakness is the most deplorable of all: sampling of sediments for charcoal analysis was not carried out in all the sites excavated. However, and despite these limitations, data assembled up to now are already very significant as they provide the single direct evidence from the woody flora; furthermore, the ecological affinities of plant species identified help us glimpse the regional diversity of the Iberian Peninsula, just before the onset of the Neolithic.

Due to the editorial restrictions, this chapter will only consider the general trends without detailing the results from the different archaeological sites. We will rely on the most significant and well-dated sites/chronological period in the different regions. Data will be presented and discussed taking into account both the regional differences and their causes and the management of the woody resources by hunter-fisher-gatherers.

The Mesolithic sites with long-term sequences display significant differences in terms of species identified and their frequencies. Despite this variability, the general trend detected reflects the transition between the Preboreal open-habitat formations dominated almost everywhere by the conifers and the Boreal mesothermophilous and thermophilous species developing in the northeast and in the south, respectively (Fig. 6.2).

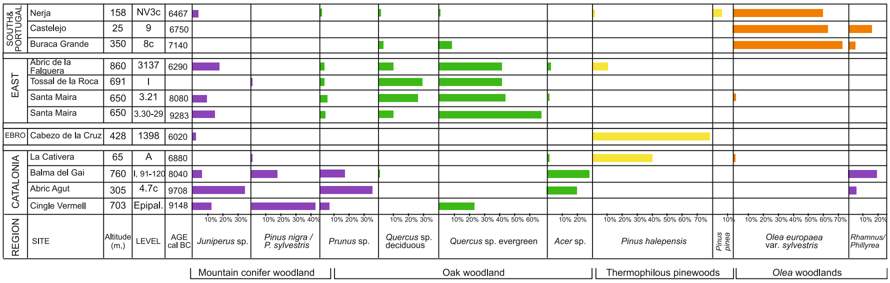


Fig. 6.2 Charcoal data from the early Holocene. Only one level per site is considered (with relevant radiocarbon dating and a statistically meaningful number of charcoal). Data after Allué (2002), Badal (1990b, 2013), Carrión (2005), Carrión et al. (2010), Figueiral and Terral (2002), and Uzquiano (1988)

During the Preboreal, a large proportion of *Juniperus* is detected in the sequences from Catalonia and 'Pays Valenciano', decreasing towards more recent moments, precisely when the curves of deciduous and evergreen oaks increase, in the east. Mountain pines (*Pinus* type *sylvestris*) linger in Catalonia but disappear further south, below 700 m altitude (Allué et al. 2012). This is a significant regional difference reflecting the interaction of latitudinal and altitudinal factors. Data assembled so far suggest a rapid retreat of pines adapted to cold environments (*Pinus* type *nigra-sylvestris*) from low/middle altitudes to the more favourable conditions of the Iberian mountains, where they still grow today. However, the persistence of *Pinus* type *nigra-sylvestris* alongside thermophilous taxa, in southern latitudes and/or low altitudes, raises doubts concerning the reliability of certain charcoal assemblages. Attention must be drawn to the fact that charcoal fragments recovered in Holocene contexts from the Alicante area and identified as *Pinus* type *nigra/sylvestris* have all been dated to the Pleistocene (Table 6.2). Other isolated finds from Preboreal contexts, such as those of Tossal de la Roca o Santa Maira, should be dated to validate (or not) the hypothesis that they could be the result of an intrusion from Pleistocene levels.

The most significant regional differences are illustrated here based on the evidence from three groups of sites with distinct floras (Fig. 6.2). *Olea europaea* dominates in southern Spain and Portugal, *Quercus* in the east, while *Pinus halepensis* predominates in the Ebro valley and in southern Catalonia. No charcoal analysis data are available from the other regions.

In Andalucia and Portugal, *Olea* dominates in sites located in the lowlands or close to the sea. It appears sporadically in the east, being identified in a single site from Catalonia, La Cativera, in a context with macrolithic industries dated 6880 cal BC and in Santa Maira, in a level dated 8080 cal BC (Allué 2002, Aura et al. 2006). AMS dating of *Olea* macroremains (charcoal and kernel) always place this species in the Boreal (Table 6.2), which indicates that the development of plant formations including *Olea* in the warmer areas of Iberia, coincides with the Boreal climatic changes which culminated in a biogeographical configuration very similar to that of today. Archaeological sites where *Olea* has been identified are all included in today's thermomediterranean bioclimatic level, i.e. in the warmer areas of the Iberian Peninsula. It has been proposed that during the colder periods of the late Pleistocene, *Olea* might have taken refuge in protected areas, from where it expanded rapidly after the end of the last glaciation (Carrión et al. 2010) in the company of other typical Mediterranean species such as *Pistacia* and *Rosmarinus*.

In the eastern areas of Iberia, the most characteristic feature is the abundance of *Quercus*, which may indicate the development of mixed woodlands (evergreen and deciduous oaks), providers of firewood during the Boreal. Other significant elements from these woodlands included *Acer*, *Fraxinus*, *Prunus*, *Rhamnus*, etc. In the case of *Prunus* and other genera mentioned here (i.e. *Rhamnus*), the range of species likely to be concerned is broad encompassing plants from very warm to very cold environments, assigned in the charcoal diagrams to different ecological formations (Fig. 6.2). Pines adapted to warmer climates (*Pinus pinea*, *Pinus halepensis* and *Pinus pinaster*) also offer interesting information in terms of

Table 6.2 Radiocarbon dates of selected woody species considered as ecological and/or anthropogenic markers

Context	Lab. Ref.	Mat.	Method	References
Solutrean	Wk-36256	Ch	AMS	Marreiros et al. (2014)
Solutrean	Wk-36255	Ch	AMS	Marreiros et al. (2014)
Epipalaeolithic	ICEN—211	Ch	AMS	Carrión et al. (2010)
Mesolithic	AA-2295	S	AMS	Carrión et al. (2010)
Upper Palaeol.	T18816A	Ch	AMS	Carrión et al. (2010)
Upper Palaeol.	OxA-20116	Ch	AMS	Zilhão et al. (2010)
Upper Palaeol.	Beta-118025	Ch	AMS	Carrión et al. (2010)
Early Neol.	Beta-165793	Ch	AMS	Carrión et al. (2010)
Neolithic	GifA-101356	S	AMS	Carrión et al. (2010)
Neolithic	OxA-6715	Ch	AMS	Rihuete et al. (1999)
Neolithic	GifA-101354	S	AMS	Carrión et al. (2010)
Neolithic	Beta-101425	Ch	AMS	Rihuete et al. (1999)
Neolithic IIB1	Beta-187433	Ch	AMS	Carrión et al. (2010)
Epipalaeolithic	Beta-158013	Ch	AMS	Aura et al. (2006)
Mesolithic	Beta-281623	Ch	AMS	Morales et al. (2012)
Mesolithic	AA-59519	Ch	AMS	García Puchol and Aura (2006)
Mesolithic	Beta-171909	Ch	AMS	García Puchol and Molina (2005)
Epipalaeolithic	GrN-29135	Ch	AMS	Picazo and Rodanés (2008)
Epipalaeolithic	GrN-29134	Ch	AMS	Picazo and Rodanés (2008)
Neololithic	Beta-90884	Ch	AMS	Rihuete et al. (1999)
Neolithic IC	Beta-303420	Ch	AMS	Badal et al. (2012b)
Chalcolithic	Beta-135665	Ch	AMS	Cámara et al. (2005)
Chalcolithic	Beta-145303	Ch	AMS	Cámara et al. (2005)
Chalcolithic	Beta-135668	Ch	Conventional	Cámara et al. (2005)
Early Neololithic	Beta-116625	Ch	AMS	Bernabeu and Molina (2009)
Gravettian	Beta-189080	Ch	AMS	Jordá Pardo and Aura Tortosa (2006)
Solutrean	Beta-189081	Ch	AMS	Jordá Pardo and Aura Tortosa (2006)
Natural	Beta-189082	W	AMS	Gómez-Orellana et al. (2014)
Epipalaeolithic	Beta-158014	Ch	AMS	Aura et al. (2006)
Neolithic	Beta-222342	Ch	AMS	Fontanals et al. (2008)
Neolithic	GrA-9226	S	AMS	Estremera (2003)
Neolithic	UBAR-314	W	Conventional	Morales et al. (2010)
Neolithic	Beta-206512	Ch	Conventional	Díaz del Río et al. (2008)
Neolithic IA	Beta-166728	Ch	AMS	Bernabeu et al. (2003)
Neolithic IA	Beta-171906	Ch	AMS	Bernabeu et al. (2003)
Neolithic	Beta-206513	Ch	Conventional	Díaz del Río et al. (2008)
Neolithic	Beta-145303	Ch	AMS	Cámara et al. (2005)

(continued)

Table 6.2 (continued)

Context	Lab. Ref.	Mat.	Method	References
Neolithic IA	Beta-162093	Ch	AMS	Bernabeu et al. (2003)
Neolithic	Beta-135663	Ch	AMS	Cámara et al. (2005)
Neolithic	GrA-8241	S	AMS	Estremera (2003)

In the column "Mat. (Material)", Ch = Charcoal, S = Seed, W = Wood. Dates have been calibrated to 2 sigma using the OxCal 4.2.3 program (Bronk Ramsey 2009) and the INTCAL 2013 calibration data set (Reimer et al. 2013)

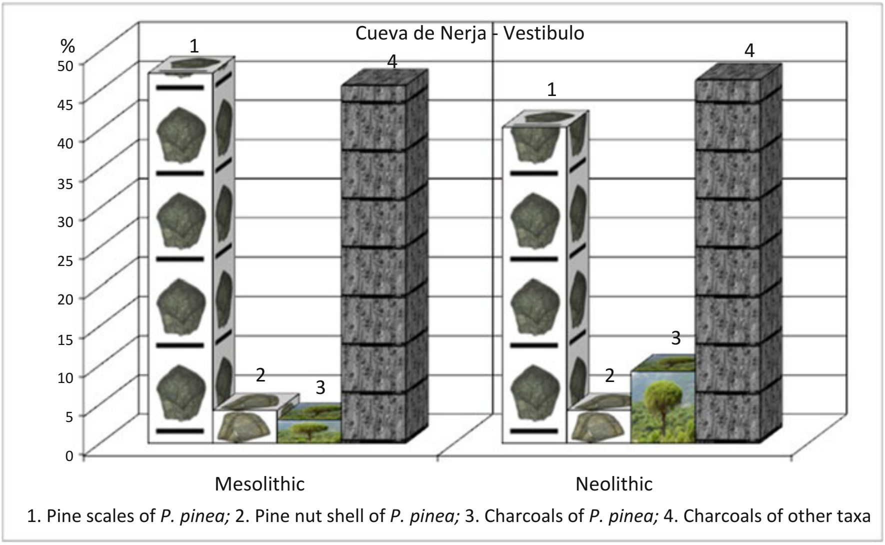


Fig. 6.3 Charred macroremains from Cueva de Nerja—Vestíbulo: level 3c (Mesolithic) and level 2 (Neolithic)

chronology and ecology; *Pinus pinea*, in particular, also provides cultural indications. This species, documented at the Cueva de Nerja since the OIS3 clearly remained in the area during the last glaciation (Badal et al. 2012a). At this site, the abundance of *Pinus pinea* macroremains (kernels and cone scales) suggests the selective management of this tree species, since the beginning of the Upper Palaeolithic (Badal 1990b). In the Mesolithic levels, *Olea* was the most important firewood used (Fig. 6.2) but the majority of charred material available comprises pine cone remains (*Pinus pinea*) (Fig. 6.3). This suggests that pine cones were collected for the recovery and consumption of their kernels. Pine cones which are collected while mature but still 'closed' (between November and March) can be stored for sometime before being exposed to the heat for the release of their kernels. This explains why the remains of pine cones are abundant while its wood is not; the advantages of protecting pine trees, providers of free nutritious food, were apparently obvious to these populations.

In Portugal, during the Boreal, *Pinus pinea* and/or *Pinus pinaster* appear to have covered large coastal and inland surfaces, in areas with sandy or siliceous soils (Figueiral 1995, Monteiro et al. 2012). The early history of *Pinus halepensis* in the Ebro valley and around Tarragona is elucidated based on charcoal data from the open-air site of Cabezo de la Cruz (Zaragoza) and the shelters of La Cativera (Tarragona) and Los Baños de Ariño (Teruel) (Badal 2013, Morales et al. 2012). Radiocarbon dating (charcoal of *Pinus halepensis*) (Table 6.2) records the precocious (Boreal) development of its woodlands in the areas of the Ebro valley and, to a lesser extent, in eastern and southern Iberia. It would appear that, during the Neolithic, it is from these dry and warm limestone areas that *Pinus halepensis* expanded to the rest of the Iberian Peninsula. This brief summary of data highlights the existence of some notable differences.

The chronological differences: In sites yielding long Preboreal—Boreal sequences, the flora characteristic of cold climates, recorded in the lowermost levels, gradually disappears. *Pinus* type *nigra/sylvestris* is a good example of these chronological differences. Absent from southern Iberia during the Holocene (between 0 and 1000 m) it still lingers in Catalonia during the Preboreal. The overall decrease/near disappearance of *Juniperus* during the Boreal also stands as a good example. These variations are interpreted as products of both the global climatic changes characterizing the early Holocene and the essential role of latitude and altitude (in the case of mountain pines).

The regional vegetation differences: Global climatic changes affected the specific flora diversity of the very different regions of Iberia, from the South to the North. In the coastal areas of Portugal and Andalucia grow thermophilous and summer draught tolerant species, such as *Olea*, *Pistacia* and *Rosmarinus*. These taxa are still present further east where charcoal fragments of *Quercus* predominate. The development of mixed woodlands of evergreen and deciduous oaks may have been favoured by the orographic configuration of the sites from the Alicante region, reached by the Mediterranean humid winds (Badal et al. 1994, Carrión 2005). Species with specific edaphic requirements (*Pinus pinaster* and *Pinus pinea*) develop in areas with sandy and siliceous soils, as in Nerja and a large proportion of Portugal; on the other hand, *Pinus halepensis* is only sporadically present in Nerja and the Alicante area, spreading instead in the Ebro valley.

The cultural differences: No clear cultural differences are detected concerning the management of woody resources. Firewood is collected in the immediate vicinity of sites and charcoal identified provides an image of local mosaic landscapes. Some plant species may have been managed for their fruits, such as *Olea*, *Pinus pinea* and *Prunus*. As mentioned above, the example of Nerja seems particularly significant of the restricted use of the wood of *Pinus pinea* to protect the production of its kernels, rich in proteins, vitamins and polyunsaturated fat. The exploitation of this freely available food during the Mesolithic of Mediterranean Europe had already been suggested by D. Clarke (1976). The same cannot be said of *Olea* despite the usefulness of its fruits, which when dully processed can be consumed. However, the amount of endocarps available is never suggestive of massive consumption, while *Olea* wood is constantly used as fuel both at Nerja and in the Portuguese sites. This suggests that this tree was constantly exploited for its wood, regardless of its fruit production (Aura et al. 2005).

6.2.2 The First Farming Communities

Plants have played a major role in supporting the life of human communities from the simple collection of leaves, fruits and firewood to their domestication. Familiarity brought knowledge. The more complex the human societies, the more complex their use of the environmental resources available became.

In the Iberian Peninsula, the first agrarian occupation takes place around 5650 cal BC in the coastal areas, and quickly expands inland, towards the Plateau, Ebro valley and the highlands of Andalucia (5050 cal BC) (Bernabeu et al. 2014, Martí and Juan-Cabanilles 2014). How did this introduction take place? The answer to this essential question can be elusive; it is however possible to show that charcoal sequences from the early Neolithic always concern sites *ex novo*, i.e. either the sites were occupied for the first time at this moment or there was a *hiatus* between the levels occupied by the hunter-fisher-gatherers and those of the Neolithic communities. Up to present not a single continuous Mesolithic-Neolithic sequence has been recorded.

In the Iberian Peninsula, the Neolithic is synonymous of 'first introduction of exotic plants' including domesticated plants (cereals) and weeds. This was the starting point of a still on-going process, which now includes herbaceous and woody plants used in a wide variety of activities. As far as we know, the first Neolithic communities arriving in Iberia with their 'economic package' were also dependent on the local wild plant resources, for their day-to-day life. The archaeobotanical data from Neolithic sites help us illustrate different aspects of life during this period, such as the importance of woodland resources for village life and woodland management; they also provide indications on how wildwoods responded to anthropogenic manipulation. As mentioned previously, the natural plant environment differed from one region to the other; it is around 5050 cal BC that the ultimate phase of stability of the Holocene vegetation (climax) is reached.

(a) Woodland resources and village life

The newly arrived Neolithic communities exploited the natural local environment to obtain a large diversity of products and, as a result, woodlands play a major role in the Neolithic economy. Plants even have a symbolic value, as suggested, for example, by the representation of trees in the rock art of La Sarga and in the impressed ware of La Sarsa (Hernández Pérez et al. 2002, 2007); these are good examples of the variety of ways in which plants could have been used by these first farming groups, and largely invisible in the charcoal record (Fig. 6.4). This is particularly well documented in waterfront sites such as La Draga (Girona, Catalonia) where biological remains are exceptionally well

Fig. 6.4 Neolithic symbolic representations of trees: (**a**) LA Sarga (Alcoi), Shelter I, panel 3, in Hernández Pérez et al. (2002); (**b**) La Sarga (Alcoi), Shelter II in Hernández Pérez et al. (2007) (image **a** and **b** by M.S. Hernández, P. Ferrer and E. Catalá); (**c**) cardial vessel from Cova de la Sarsa (Bocairent), unpublished drawing courtesy of E. Cortell

preserved (Bosch et al. 2000, 2006, 2011). Local woodlands provided raw materials for building, artefacts and tools, domestic and artisanal firewood. Mediterranean woodlands also supported hunting while providing grazing and browsing for domesticated animals (Badal 2002).

Data from La Draga provide valuable insights into the life of a Neolithic community, which are not usually available in less exceptional settlements. The waterlogged conditions allowed the remarkable preservation of very fragile material, such as leaves of *Laurus nobilis*, ropes and ties/laces made out of *Clematis vitalba* and *Carex* sp., and even six species of *fungi* (Bosch et al. 2011).

The analysis of waterlogged wood and charcoal remains led to the identification of 23 taxa, relating to two vegetal formations: the deciduous oak woodland with associated species and the riverine vegetation. Main components include oak, box and laurel, species employed as fuel, as timber and as raw material for the making of artefacts. Eighteen different species were considered suitable for the manufacture of implements and objects (Fig. 6.5a); necklace beads were made out of endocarps of *Prunus avium* while plant fibres were used to make ropes and baskets, etc. (Bosch et al. 2000, 2006, 2011).

The collection of firewood seems to have targeted a large array of species both in the oak-dominated woodland (deciduous *Quercus*, *Buxus*, etc.) and in the riverine forest (*Laurus*, *Corylus*, *Salix*, *Fraxinus*, *Ulmus* and *Alnus*) (Fig. 6.6). The repeated identification of *Laurus nobilis* is particularly striking as the history of this species in Iberia remains unclear; however its concomitant presence in other distant Mediterranean sites such as Cova de les Cendres and La Guineu suggests a large distribution area, reaching from Girona down to Alicante, at least.

Similar evidence from other sites support the concept that the collection of firewood is essentially random, lacking any obvious selection (Fig. 6.5b). On the other hand, such a selection obviously existed for other activities such as the making of domestic implements (furniture, basketwork containers, wooden vessels, etc.) and agrarian instruments. The craftsmanship displayed makes it obvious that Neolithic populations were aware of the qualities of the different plants and of their suitability for the different activities.

The skills of these populations, well documented at La Draga, can only be deduced in the sites where only charred material survived; In these sites, it is however apparent that many more plants were used than those surviving as charcoal; this is suggested by the exceptional finds of a basket container made out of *Stipa tenacissima* (Cova de les Cendres) (Bernabeu and Molina, 2009) and the sandals and baskets from Cueva de los Murcièlagos de Albuñol (Góngora, 1868). These sites where only charcoal is preserved are better suited to reconstruct forest composition and availability of plant resources; at La Draga, 14 taxa (out of a total of 23) were clearly used as firewood (Fig. 6.5a), and these are representative of managed forests (oak and riparian); the diversity

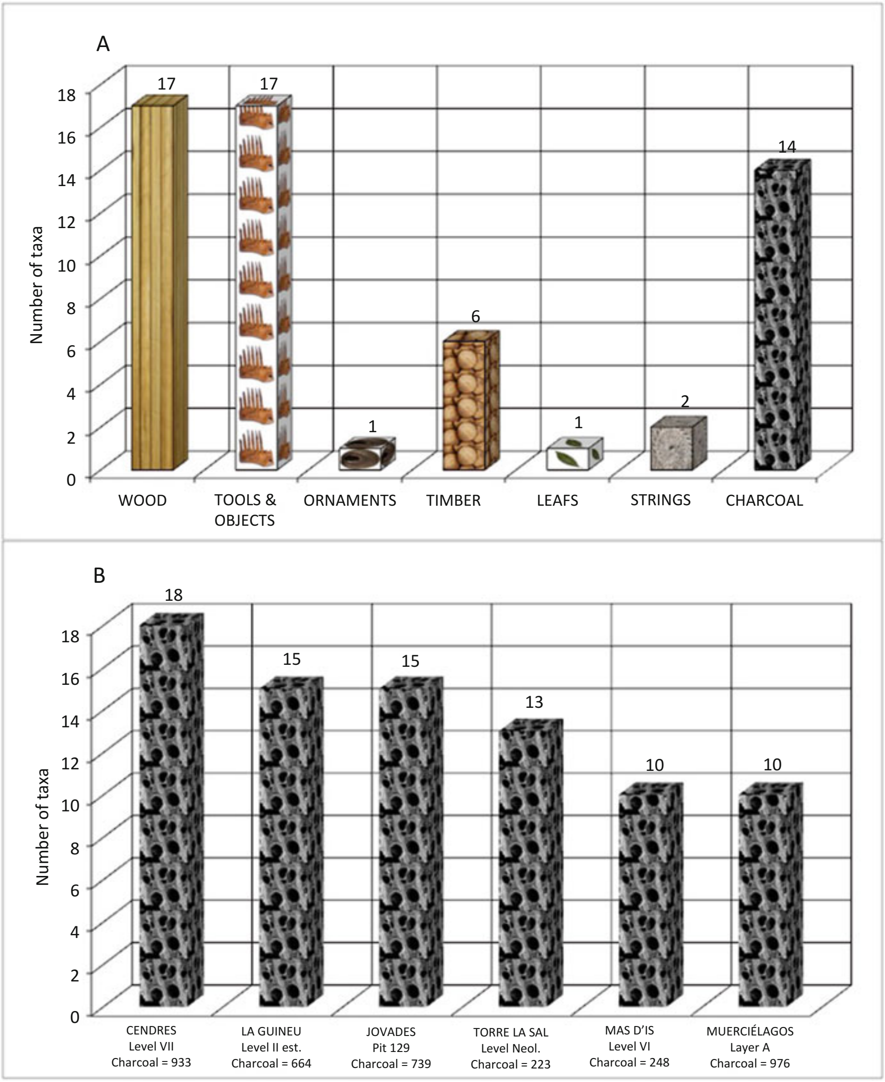
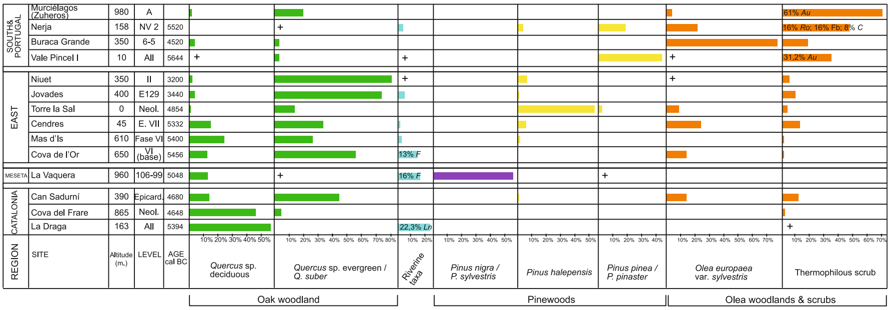


Fig. 6.5 (**a**) Number of vegetal taxa identified at La Draga for different uses (data after Bosch et al. 2000, 2011; Caruso and Piqué 2014). Pictures from J.S. Carrera, F. Antolín (Team of La Draga) and E. Badal. (**b**) Number of vegetal taxa used as firewood in other Neolithic sites (data after Allué et al. 2009; Badal 1990b, 2009; Carrión 2005, 2009; Rodríguez-Ariza 2011)

of taxa identified in the charcoal record from other less exceptional sites, sometimes even higher than at La Draga, must therefore be representative of the surrounding forests.



Au: Arbutus unedo; C: Cistus sp.; *F: Fraxinus* sp.; Fb: Fabaceae; *Ln: Laurus nobilis; Ro: Rosmarinus officinalis*

Fig. 6.6 Charcoal data from selected Neolithic sites. Only one level per site is considered (with relevant radiocarbon dating and statistically meaningful number of charcoal). Data after Badal (1990b, 2009), Badal et al. (2012b), Caruso and Piqué (2014), Carrión (2005, 2009), López et al. (2003), Rodríguez-Ariza (2011), Ros Mora (1992), and Figueiral and Terral (2002)

(b) The Neolithic woodland

Regardless of chronology (Early or Late Neolithic) and location, charcoal analysis spectra from archaeological horizons formed during the first farming/herding occupation are always dominated by key woodland species and reflect the composition of the climax Holocene woodlands.

In the cold highlands, mountain pines predominate (*Pinus* type *sylvestris*), the humid lowlands are the domain of deciduous oak woodland, in the sub-humid or dry lowlands the deciduous oaks mix with evergreen oaks, while *Olea* develops in the dryer and warmer areas (Fig. 6.6).

The development of the climax vegetation depends on different factors, climate usually being the most important. Latitude, altitude, topography, soils, hydrology and edaphism explain the variations recorded in different sites. For example, *Pinus* type *sylvestris* dominates at Cueva de la Vaquera (altitude: 960 m) while more thermophilous species, such as *Arbutus unedo*, *Olea* and *Pistacia* predominate at Cueva de los Murciélagos de Zuheros (899 m); Buraca Grande (350 m) (Figueiral and Terral 2002; López et al. 2003; Rodríguez-Ariza 2011). Edaphism influences the development of stands of mixed pines (*Pinus pinea* and *Pinus pinaster*) (Table 6.2) on the estuary areas, siliceous substrates, coastal and continental dunes of Portugal, Douro Valley and southern Andalucia (Carrión 2005; Figueiral 1995; Morales-Molino et al. 2011; Gómez-Orellana et al. 2014). Exploitation of *Pinus pinea* for its kernels is further recorded at Nerja and in different Portuguese sites (Fig. 6.3).

The riverine vegetation is exploited in all the sites, but to a lesser degree than the other woodland formations. *Fraxinus*, *Salix* and *Populus* are present everywhere while *Corylus avellana* is restricted to the more humid and more northern sites. Another riverine Mediterranean species, the wild *Vitis*, is recognized at Cova 120, Cova de les Cendres and La Draga (Ros Mora 1992, Badal 2009, Caruso and Piqué 2014).

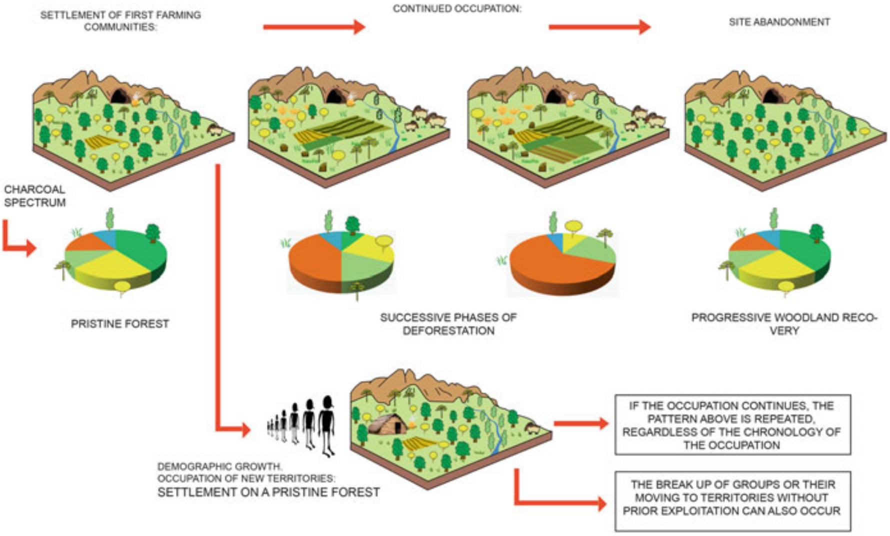


Fig. 6.7 Hypothetical vegetation dynamics in relation to the occupation pattern

Charcoal spectra allow us to recognize the composition of the different vegetal formations. They are however powerless in terms of physiognomy. At La Draga, the dendrological study carried out based on 233 wooden poles points to the use of adult trees suggesting the existence of mature woodlands (Bosch et al. 2000). It seems highly probable that similar patterns may exist elsewhere.

Based on the qualitative and quantitative data available, it seems likely that the Mediterranean evergreen woodlands covered large surfaces, and were the first to be exploited by the Neolithic communities. Based on AMS dates from Cova de l'Or and Cova de les Cendres (Badal 2009; Badal et al. 2012b) it is possible to suggest that during the first 300–500 years of Neolithic occupation, either in a cave/shelter or in an open-air settlement, no significant vegetation changes are detected, in comparison with the late Mesolithic plant cover. This may result from a balanced management of resources, stable demography and reduced livestock (Badal 2002). However, after this interval, evidence of human impact is clearly recorded in sites with long-term occupation. In Iberia, this dynamic is better documented in caves (Figs. 6.7 and 6.8).

(c) The reaction of vegetation to Neolithic management

In eastern Iberia, the first farming communities consisted of a small number of families, who lived in two types of sites: in small open-air settlements with a few huts, such as Mas d'Is and Benàmer, or in natural caves, such as Cova de l'Or, Cova de les Cendres, Cova d'En Pardo and Abric de la Falguera (Bernabeu et al. 2003 ; Bernabeu and Molina 2009; García Borja et al. 2011; García Puchol and Aura 2006; Martí et al. 1980; Torregrosa et al. 2011). During the earliest part of the Neolithic, these caves were used either as 'proper' settlements or as auxiliary and satellite sites of other settlements. There is evidence everywhere

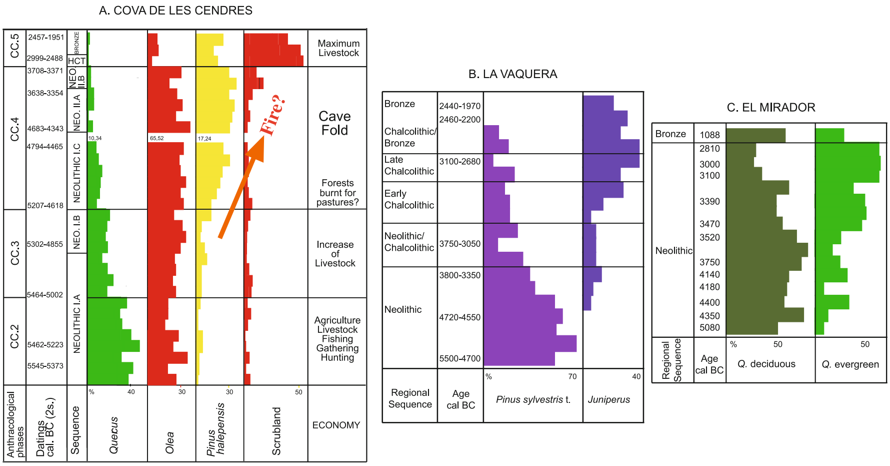


Fig. 6.8 Charcoal analysis sequences from three caves with long-term occupation illustrating the expected dynamics of woody vegetation after several centuries of farming (after Badal 2009; López et al. 2003; Allué and Euba 2008)

that the economy is based on agriculture and livestock. Hunting, fishing and gathering were complementary activities recognized in all types of settlements. The first Neolithic groups would have needed to exploit versatile productive territories, able to support an auto-sufficient farming economy (Badal et al. 2012b).

Relevant data assembled indicate that 300–500 years after the first Neolithic occupation, which corresponds to the Cardial and Epicardial Neolithic (Neolithic IA and IB), herding activities in caves intensified, culminating during the Neolithic II (fifth millennium BC). At the same time, the number of open-air settlements in valleys increased and a tendency towards the specialization of the territory began; herding would have been the main activity in caves while production in open-air settlements would have been more diversified. Caves would have been either independent pastoral territories that exchanged products with open-air settlements or most probably enclosures for livestock associated with the villages (Badal et al. 2012b). Pastoral caves are well known in the western Mediterranean: Cova de les Cendres, Cova de l'Or, Abric de la Falguera, La Guineu, El Mirador, La Vaquera, etc. (Allué and Euba 2008, Allué et al. 2009, Badal et al. 2012b, Bernabeu and Molina 2009, Estremera 2003, García Puchol and Aura 2006). Following continuous occupation, the natural vegetation dynamics is altered by human activity and after the first 300–500 years, its effects are seen in the charcoal sequences. Distinctive details help us detect the changes in charcoal sequences covering different cultural periods; firstly, the diachronic variations in the proportion of main taxa (*Quercus*, *Olea* and *Pinus*); secondly, the appearance or disappearance of plants particularly sensitive to farming activities. As a result, and despite the problems felt when trying to generalize, it seems possible to outline the vegetation dynamics in the different ecological regions of the Iberian Peninsula.

In the dry/sub-humid areas (mean annual precipitation: 350-1000 mm), the dominant mixed deciduous and evergreen *Quercus* woodlands of the first phase will be gradually replaced by pine stands of *Pinus halepensis* or by scrub vegetation. This dynamic is recorded, for example, at Cova de les Cendres (Fig. 6.8a), Cova de l'Or, Polideportivo Martos and other sites (Badal 2009, Badal et al. 2012b, Rodríguez-Ariza 2011).

At Cova de les Cendres and Cova de l'Or the phase when *Pinus halepensis* dominates corresponds to dung levels (Fig. 6.6). *Olea* and matorrals increase significantly in the same levels. The vegetation changes recognized may have been the result of changes in woodland management, now oriented towards stockbreeding. At Cova de les Cendres, the dominance of the Aleppo pine is recorded at 4880 ± 120 cal BC (Fig. 6.8a). At Cova de l'Or, a charcoal fragment of *Pinus halepensis*, dated 3900 ± 70 cal BC (Table 6.2), allows us to place the change in the late fifth and early fourth millennium cal BC., when secondary formations with Aleppo pine compete with the oak woodland. The abundance of *Olea* in these sites or of *Fraxinus* in Abric de la Falguera may result from the use of these trees for fodder, due to the good quality of their leaves as animal food (Badal 2009, Carrión 2005).

Herding activities may have caused the first serious changes to the 'pristine' Mediterranean woodland (Badal 2002, 2009). The increase of Aleppo pine could be related to controlled woodland burning in order to create pasture areas. This could also explain the Chalcolithic and Bronze Age low matorral at Cova de les Cendres (Fig. 6.8a). The duality of the landscapes, natural (Cardial contexts) and anthropogenic (post-Cardial and epicardial contexts) started at the time when more intensive farming led to woodland changes which are also documented (Fig. 6.7) by palynology and sedimentology (Badal et al. 2012b).

In the Cueva de los Murciélagos (Zuheros, Andalucia), the xerophilous/thermophilous formations dominated by *Arbutus unedo*, *Olea* and *Pistacia* contract in favour of the low 'matorral' dominated by *Cistus*, *Erica* and *Rosmarinus* (Rodríguez-Ariza, 2011). Again, differences amongst Neolithic—Bonce Age sequences in the studies regions can be explained by both human activity and the biogeographic characteristics of each area.

In the continental areas of the highlands (around 1000 m), pine stands (*Pinus* type *nigra-sylvestris*) will be replaced by juniper at La Vaquera (Segovia) (Fig. 6.8b) and mixed oak-dominated woodlands (deciduous and evergreen *Quercus*) at Cova Fosca (Castellón) (López et al. 2003; Antolín et al. 2010). In the sub-humid/humid areas (mean annual precipitation: 600–1500 mm), deciduous *Quercus*, dominant during the first occupation by farming communities, will be replaced by evergreen *Quercus* in sequences from caves. This process is particularly well illustrated at Cova del Frare, La Guineu (Catalunya) and Cueva del Mirador (Northern Plateau) (Fig. 6.8c) (Ros Mora 1992; Allué et al. 2009; Allué and Euba 2008). The dynamics of the vegetation in these areas has much in common with that from southern France discussed below.

6.3 Neolithic Vegetation in Southern France, at Low and Middle Altitudes

6.3.1 The Ancient and Complex History of Landscapes

The Mediterranean landscapes which now characterize the areas at low and middle altitudes are a result from the postglacial climate warming and subsequent human impact. A thermal optimum (temperate climate) is observed during the beginning and the middle of the Holocene (Magny 1995). However, climate was not stable, and moments of global or European climatic deterioration were recorded at different stages (Alley et al. 1997; Bond et al. 2001, Magny 1995).

During the first part of the Holocene, vegetation seems to reflect the climatic conditions only while from the Middle Neolithic onwards, vegetation is altered by human agency (Vernet and Thiébault 1987; Chabal 1997; Pons and Quézel 1998; Magny et al. 2002; Delhon et al. 2009). During the second part of the Holocene, it is difficult to identify the cause-and-effect mechanisms responsible for the changes detected. Climatic variations may have accelerated or slowed down natural forestry dynamics, alternatively; they may also have affected the intensity of the effects of human activities on the vegetation (e.g. forest clearance leads to dryer local conditions, which will be amplified if the climate becomes dryer at the same time). This quest requires the analysis of the ecological affinities of plants and their competitive behaviour, which regulate ecological balance, and the effect of environmental conditions and agricultural communities on that equilibrium.

Holocene vegetation transformations recorded by charcoal analysis in southern France prompted the definition of regional phases (Vernet and Thiébault 1987) which largely reflect the global landscape evolution:

Phase 1 (11000–6000 BC, Epipalaeolithic and Mesolithic): maximum of *Pinus* type *sylvestris* and *Juniperus*, disappearance of *Betula*, appearance of deciduous *Quercus*.

Phase 2 (6000–4000 BC, first part of the Neolithic): *Juniperus* decreases, expansion of deciduous *Quercus*, presence of evergreen *Quercus* and other thermophilous species. First evidence of *Pinus halepensis* in Provence.

Phase 3 (4000–2500/2000 BC, Middle and Late Neolithic): human induced changes of the vegetation with a decrease of deciduous *Quercus*, favouring plants with a good capacity for resprouting (*Quercus ilex*, *Quercus coccifera*, *Phillyrea*, *Rhamnus*, *Arbutus unedo*) and colonizers (*Buxus sempervirens*, *Pistacia*, *Cistus*, *Erica*...).

Phase 4 (from 2500/2000 BC onwards): maximum of cultural landscapes, importance of ‘matorrals’.

This general model and its inter-regional variations is at the basis of our approach. However, more recent studies suggest the existence of spatial, structural and chronological heterogeneities which must be investigated.

6.3.2 The Mesolithic Flora Diversity, Inherited from the Climatic Warming

In the Mediterranean region, the climatic warming generated rising sea levels and changes in the geographic configuration. The new conditions favoured the expansion of plant species from their refuge areas and the re-establishment of woodlands (Quézel and Médail 2003). In southern France, the herb-steppe formations are replaced by forests adapted to cold conditions. The majority of the Mesolithic sites (Preboreal, Boreal and early Atlantic) feature pioneer forests dominated by *Pinus* type *sylvestris* and *Juniperus*. The site of Abeurador, located at mid altitude (Fig. 6.1, Table 6.1), is a good example: the dominance of *Pinus* type *sylvestris* is followed by the dominance of *Juniperus* and the regular increase of deciduous *Quercus*, from the Epipalaeolithic to the middle Neolithic (Heinz 1990). A similar sequence is recorded in the pollen diagram of St-Sauveur, by the coast (Puertas 1998). Variations to this scheme are recorded in sites with different geographical and altitudinal settings. At Balma Margineda, located in Andorra, in the supra-mediterranean vegetation level, *Pinus uncinata* predominates over *Pinus sylvestris* and *Juniperus*, while the deciduous oak appears in the end of the Mesolithic (Heinz 1990). At Fontbrégoua, the last moments (Sauveterrien-Late Mesolithic) of the 'cold' woodlands dominated by *Juniperus* give way to Mediterranean species characteristic of open spaces (Thiébault 1997). Similarly, at Cova de l'Esperit, in a thermo-mesomediterranean context, *Juniperus* dominates in the Palaeolithic and Mesolithic levels while the near-absence of *Pinus* type *sylvestris* is noticed (Solari and Vernet 1992). These vegetation successions are relatively similar, displaying however altitudinal or regional bioclimatic differences, expressed in terms of chronological gaps or dominant taxa.

And yet, certain sites display important local particularities, difficult to explain, such as the near-absence or the dominance of certain taxa, suggesting landscapes which no longer exist.

This is, for example, the case of Cova de l'Esperit where the vegetation dominated by *Juniperus* is quickly replaced by *Quercus coccifera/ilex*, *Olea europaea* and *Phillyrea/Rhamnus*, while deciduous oaks remain absent. *Phillyrea/Rhamnus* reaches significant frequencies (10%) during the period Late Mesolithic—Early Bronze (Solari and Vernet 1992). This taxon is identified as early as c. 9000 BC (Henry 2011), and is frequently recorded in the Neolithic sites. At La Font des Pigeons, *Phillyrea* sp. is remarkably abundant (30–60%) between the Mesolithic and the Middle Neolithic, dominating in association with, first *Juniperus* and later *Pinus halepensis*; *Quercus* deciduous is nearly absent (Thiébault 1999). These shrubs, which can develop to tree-like stature and are relatively resistant to cold conditions (Delhon et al. 2010), are likely to have developed precociously, becoming an important component of the mature forests. At Arene Candide (Ligurian coast) the curves of *Phillyrea* sp. and deciduous oak follow the same pattern, increasing during the early Neolithic decreasing thereafter, while *Quercus coccifera*/*ilex* only expands later on (Thiébault 2001). At Font Juvénal, frequencies of *Phillyrea*/*Rhamnus* remain constant and significant from the early Neolithic to the Iron Age (Thiébault and Vernet 1992). These data suggest that *Phillyrea*/*Rhamnus* are normal components of the hardwoods, both during the Neolithic and in the following periods. It is possible to envisage that *Phillyrea latifolia* played a significant role in the midst of the deciduous forest and in the subsequent coppiced woodlands, already in competition with Holm oak. *Phillyrea angustifolia* and *Rhamnus alaternus*, more light-demanding species, may have behaved as pioneers or simply grown in open areas.

Several authors also draw attention to the importance of Prunoideae (*Punus spinosa*, *P. mahaleb*, *P. avium*, *P. amygdalus*) during the Epipalaeolithic and the Mesolithic, in association with the Maloideae, all light-demanding plants. During earlier periods, these taxa could be interpreted as marking first the onset of colder conditions and later the arrival of the deciduous oak-dominated woodland, as illustrated at Troubat in the Pyrenees, from the Magdalenian to the Sauveterrian (Heinz and Barbaza 1998). In other areas (eastern Languedoc-western Provence) they have been interpreted as indicating dry conditions during the transition Lateglacial/Postglacial (Bazile-Robert 1980). Evidence from Grotte du Sanglier, in the Lot district, dates the development of the oak-dominated woodland to the end of the Azilian, when Rosaceae decrease (Théry-Parisot 2001b). They seem to constitute a pre-forest phase, as also noticed in the caves of Fieux, Escabasses and Cuzoul de Gramat, between the early and the Late Mesolithic (Henry et al. 2012). At l'Abeurador, Prunoideae and Maloideae remain the constant background to the development of the Neolithic oak forest (Heinz 1990). Later on, the presence of Prunoideae (including *Prunus spinosa*, untouched by animals) in other sites suggests a link with anthropogenic pressure. Prunoideae and Maloideae form a heterogeneous group in terms of ecology and their abundance seems to be associated with open environments, but in different bioclimatic contexts and in different moments of the vegetal succession.

6.3.3 The Development of Temperate Woodlands and Regional Variations

In the majority of sites, the spontaneous extension of the temperate oak-dominated woodland (probably *Quercus pubescens*) took place during the Late Mesolithic as a result of climatic change. Other deciduous genera such as *Acer*, *Tilia* and Rosaceae are present, in sporadic association with Mediterranean species (Vernet and

Thiébault 1987; Heinz 1990; Heinz and Thiébault 1998). In the supra-mediterranean level, the development of this oak-dominated forest happens earlier, as seen at Grotte de Pégourié since c. 9000 BC (Solari and Vernet 1995) or at Fieux, c. 7000 BC (Henry et al. 2012).

Charcoal analysis detects these forests in the hinterland, while pollen analysis records them up to the coast (Puertas 1998), which shows the vast distribution of these supra-mediterranean woodlands even in more thermophilous areas, vindicating the suggestions proposed by ecologists working with present day vegetations (Quézel and Médail 2003). Deciduous woodlands will dominate the coastal areas up to the beginning of the Bronze Age, before receding due to edaphic conditions, in favour of alluvial woodlands rich in *Fraxinus* and *Ulmus* (Cavero and Chabal 2010; Court-Picon et al. 2010).

It is in this context that Neolithic populations settle and develop their new way of life.

The deciduous oak forest is not dominant everywhere in southern France, as a result of regional climatic differences. In Provence, at Fontbrégoua, *Pinus halepensis* predominates already during the early Neolithic; pine and deciduous oak woodlands are exploited during the Middle Neolithic (Thiébault 1997). In the Languedoc, the native *Pinus halepensis* is rarely identified before its spread after the Roman period (Chabal and Durand 1990). This thermophilous species, growing in all types of soils, tolerates draught and is well adapted to fire. Its presence may reflect regional ancient differences due both to the different climatic conditions and prehistoric human behaviour, especially concerning the use of fire. Good conditions for the spread of this heliophilous plant may have been available at different moments: after the regression of the cold floras, in the open spaces being colonized by oak, and much later, following the sustained anthropogenic exploitation of the oak-dominated woodlands.

The abundance of wild *Olea* is also noticed in the Roussillon (Cova de l'Esperit) from the Late Mesolithic to the Middle Neolithic (Solari & Vernet 1992) and in Provence, from the early Neolithic (Arene Candide) or the Middle Neolithic (Giribaldi) onwards (Thiébault et al. 2004). These wild populations, spreading out of their glacial refuge areas, may have grown here in riverine contexts (Thiébault et al. 2004, Terral et al. 2004).

6.3.4 The Neolithic Societies Transformed the Deciduous Oak-Dominated Woodlands

No significant changes are recorded during the Late Mesolithic and the early Neolithic concerning the mature oak-dominated forests. Their exploitation is not synonymous of deforestation. The first modifications are expressed in terms of physiognomy: cuts/slash-and-burn of the deciduous species result in immediate resprouting (coppicing or suchering), which means that forest composition remains the same. This is well illustrated at Grotte Lombard where deciduous *Quercus* dominates an assemblage comprising species of both temperate (*Acer*, *Tilia*, *Ilex aquifolium*, *Prunus*) and mediterranean (*Quercus coccifera*/*ilex*, *Buxus sempervirens*) climates (Thiébault 2001). At Font Juvénal, deciduous *Quercus* also dominates during the Cardial and Epicardial, when *Phillyrea* sp., *Acer monspessulanum*, *Acer campestre*/*opulifolium* and *Prunus* sp. are also identified. The first precoceous moderate changes are detected at Grotte du Taï, with the regression of deciduous *Quercus* during the Epicardial (Chabal unpublished). Similar precoceous clearances (early Neolithic) are recorded by the palynology, based on the appearance of cereals and higher frequencies of herbaceous plants (Jalut 1995; Puertas 1998).

The remarkable sequence of Font Juvénal (Figs. 6.1, 6.9, 6.10, Table 6.1) illustrates the subsequent vegetation evolution (Heinz and Thiébault 1998). During the Middle Neolithic (Classic Chasséen) a slow regression of deciduous *Quercus* is identified while frequencies of *Quercus coccifera*/*ilex* and *Buxus sempervirens* increase, especially from the Late Chasséen up to the end of the sequence. These transformations result from forest exploitation. The first cuts rejuvenate the forest, stimulating wood production and starting a cycle that can last for hundreds of years, until constant coppicing/pollarding slows down the regeneration of *Quercus pubescens*. This is when the more resilient *Quercus ilex* becomes dominant. In the long run, a new dynamic stability is reached. Species adapted to vegetative regeneration and light-demanding plants (*Pistacia*, *Cistus*, *Erica*...) are favoured. Understory plants such as *Buxus*, left un-grazed by animals, also prosper.

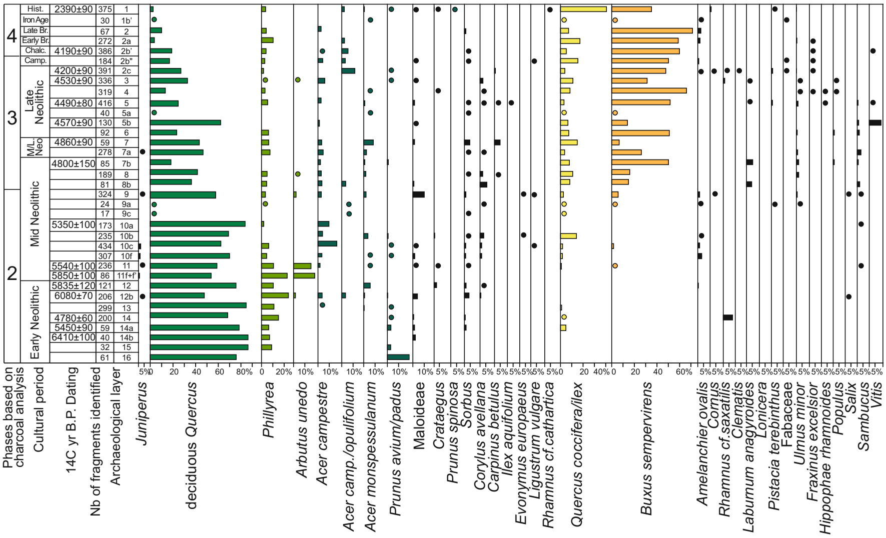
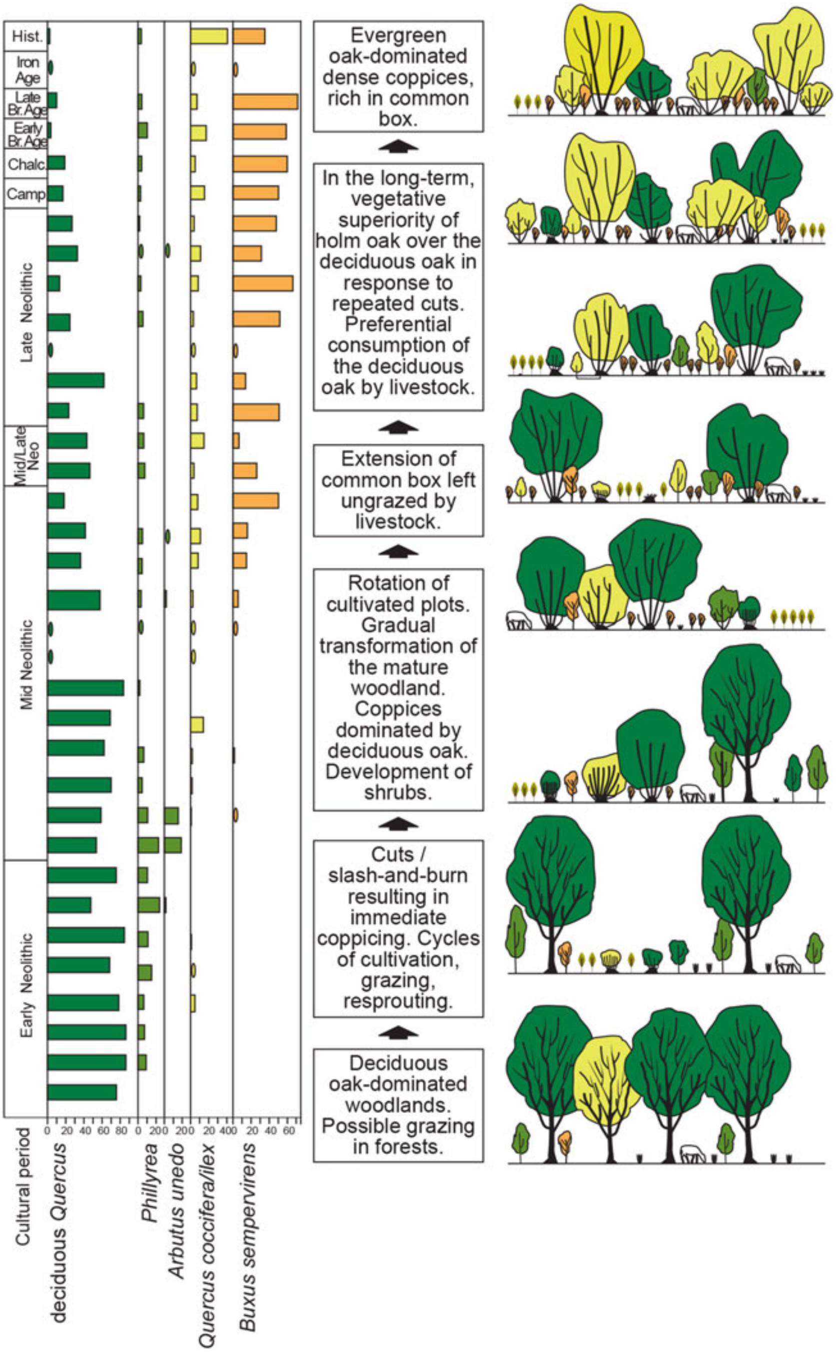


Fig. 6.9 Charcoal analysis diagram of Font Juvénal (Aude, France) (after Thiébault & Vernet 1992)



Evergreen oak-dominated dense coppices, rich in common box.

In the long-term, vegetative superiority of holm oak over the deciduous oak in response to repeated cuts. Preferential consumption of the deciduous oak by livestock.

Extension of common box left ungrazed by livestock.

Rotation of cultivated plots. Gradual transformation of the mature woodland. Coppices dominated by deciduous oak. Development of shrubs.

Cuts / slash-and-burn resulting in immediate coppicing. Cycles of cultivation, grazing, resprouting.

Deciduous oak-dominated woodlands. Possible grazing in forests.

Fig. 6.10 Schematic illustration of the forestry changes recorded at Font Juvénal (Aude, France) based on main taxa only

This scheme is also observed in other Neolithic sites, with variations concerning dominant species. The impact of human activities (repeated forest cuts, fires grazing) changes the relationship amongst plant species. The more resistant to repeated cutting (*Quercus ilex*, *Phillyrea latifolia*, *Arbutus unedo*) start by forming dense, closed formations. Elsewhere, plants regenerating well after fire events (*Pinus halepensis*, *Quercus suber, Erica arborea*) gradually replace the deciduous oak (Vernet and Thiébault 1987; Chabal 1997; Heinz and Thiébault 1998). After a variable time span, the open areas multiply as a result of cultural and economic practices, soil pedological regression and erosion. In the long term, coppiced evergreen oak also grows old and, after 150–200 years, the roots eventually become exhausted; the sexual regeneration of this species apparently requires the extension of the deciduous oak, whose seedlings never disappear (Fabre 1996).

The Middle Neolithic is the starting point for these changes, with the development of larger villages, and a more complex economy. But the oak woodland will change according to the same processes from the Middle Neolithic up to the present, as illustrated at Sallèles d'Aude, a Gallo-roman potter's village. Charcoal analysis records the replacement of deciduous *Quercus* by *Quercus coccifera/ilex* as a result of three centuries of wood exploitation by the potters (Chabal 2001). The ecological dynamics at Sallèles d'Aude and at Font Juvénal follows the same pattern. Only the time span and type of exploitation differ: 4000 years of agropastoral pressure at Font Juvénal versus 300 years of firewood exploitation at Sallèles d'Aude.

This lack of synchronism, also observed during other periods, constitutes unequivocal evidence for the anthropogenic origin of this evolution. Furthermore, forest changes are not cumulative; they can be reversed when human impact decreases. With the exception of permanent fields, the oak woodlands will regenerate spontaneously, with recurrent cycles of exploitation and regeneration (Chabal 1997).

6.3.5 A Mosaic of Landscapes for Each Period

In the Languedoc region, the comparison of charcoal spectra from seven Late Neolithic sites records the co-existence of wooded landscapes, with different levels of transformation (Fig. 6.11). The sites located in different ecological settings (altitude from 12 to 400 m) include:

- In the Hérault district: Rocher du Causse (Chabal, 1997), Boussargues (Figueiral 1990), Les Vautes (Chabal 2003), Richemont (Figueiral 1990), Port Marianne-Espace Richter (Chabal 1997).
- In the Gard district: Les Pins (Chabal unpublished), Moulin Villard II (Chabal 1997).

The Mediterranean mixed oak woodland dominates but different *facies* are noticed based on the proportion of the different species involved and on the degree

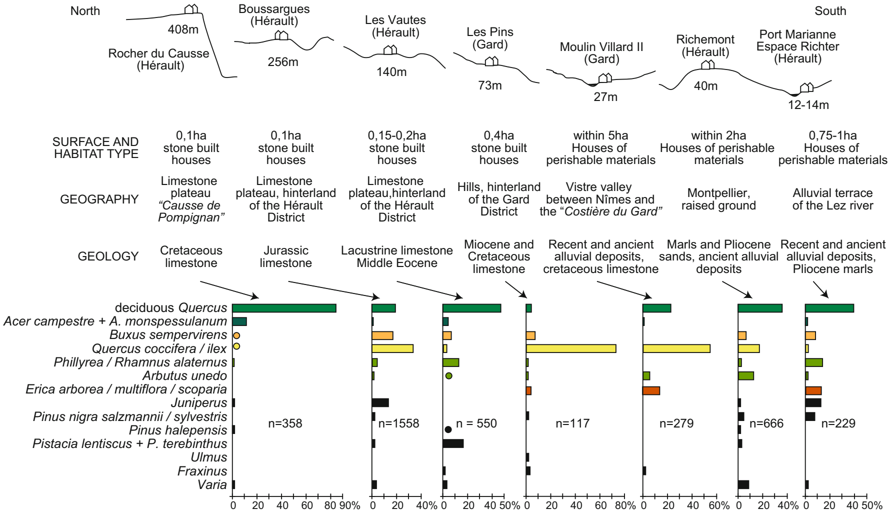


Fig. 6.11 Comparative charcoal diagrams from seven Late Neolithic/Chalcolithic sites located in the Languedoc region, according to their specific contexts

of maturity of the different stands. For example, deciduous *Quercus* dominates at Rocher du Causse, while *Quercus coccifera/ilex* predominates in the sites from the Gard.

These small agropastoral communities required around 2m^3/year of firewood per person. For example, the needs of 40 people could easily be satisfied by the exploitation of a reduced area (within a radius of 400 m) (Bourquin-Mignot et al. 1999). In each site, the overall data from charcoal analysis are a synthesis of repeated collections of firewood, which represent the mean proportions between species in the nearby vegetal environment composed of mature woods, coppiced woods and open spaces.

Differences between sites can be explained either by the different natural conditions or by human activities. As an example of the first, we can cite Rocher du Causse, which is situated inland at 400 m altitude, where mean precipitation is higher than by the coast. This may explain why deciduous oaks thrived during the Neolithic. At present, this area is better suited to the development of *Quercus ilex*, but this is a consequence from many centuries of exploitation which favoured this species and from the decreasing water retention capacity due to erosion. Conversely, in the coastal sites lower precipitation rates were not compensated by soil water reserves as topography was favourable to drainage.

Other differences concern the East-West distribution of sites. Higher frequencies of *Quercus coccifera/ilex* are registered in the Gard than in the Hérault. Nowadays, it rains less in the Gard and the winds are dryer. By the Late Neolithic, the hydrologic balance must have been already less favourable in this area.

In short, in the eventuality of a similar woodland exploitation, deciduous *Quercus* would be favoured at Rocher du Causse, less favoured in the more coastal sites (Hérault) and even less favoured in the sites located in the Gard. It is according to this gradient that the relationship *Quercus pubescens*/*Quercus ilex* must be understood.

Are the other differences between sites under the control of human activities? In this case, they would be dependent on the forestry heritage, continuity (or not) of occupation, demography, agropastoral practices, etc. These data are rarely available at the same time. These factors must be interconnected, as it is difficult to consider the complete separation between woodlands and cultivated fields. We must therefore imagine a dynamic and cyclic exploitation of the very same areas (firewood/farming/pasture) dependant on the recovery speed of coppiced woods (Chabal 1997).

Furthermore, the anthropogenic impact on the vegetation cannot be considered in terms of intensity or type of activities, only. In the same way that vegetation potentialities are determined by natural factors, these in turn change their reaction to human impact. Under the same degree of exploitation, deciduous oaks will resist longer to the advance of Holm oak, when growing in altitude or in deep soils. The problem arises when trying to distinguish the effects of light anthropogenic impact from those of particularly good natural conditions, or conversely, the effects of intensive human impact from those of a very dry period.

It is possible that, during the first half of the Neolithic—especially in areas located in the supra-mediterranean level or under oceanic influence—the degree of humidity might have been responsible for the slowness of the process replacing one oak for the other. On the other hand, human action can also modify the relation between vegetation and natural factors (with the exception of their extreme values). Deforestation may change pedological evolution, destabilize water reserves and influence the development of certain species in the same way as drier climatic conditions. This is why, it is impossible to overlook the interaction between natural and anthropogenic factors.

Finally, the overall condition of woodlands, also conditions the effects natural factors might have in their growth. The hydrology balance is influenced by the vegetation cover which controls evapo-transpiration and retention of run-off water or flood water. It also reduces temperature extremes (day/night/seasonal) atmospheric hygrometry, wind, etc.

At a given time, in southern France, charcoal analysis identifies different stages of forestry dynamics and diverse landscape physiognomies which illustrate chronological gaps of natural or anthropogenic origin. Vice versa, we also observe identical dynamics separated by long time spans, but with different speeds; it is only recently that human activities led to the secondary standardization of landscapes.

6.4 Conclusion

The post glacial climate warming is at the origin of the great floristic diversity recorded both in the Iberian Peninsula and in southern France, as plant species 'escaped' their refuge areas and rapidly spread. The deciduous Mediterranean woodlands, with analogies with the European temperate forests, reach their optimum expansion during the Boreal/beginning of the Atlantic. During this period, any possible impact from the hunter-fisher-gatherer societies cannot be detected.

The settlement of the first farming/herding communities, regardless of its precise timing, takes place in almost 'intact' forested areas as confirmed by the archaeobotanical data.

The first human disturbances of the forest would have changed its physiognomy, from mature to coppiced/pollarded woods, but preserved its composition. This is why the first transformations are not immediately registered by charcoal analysis, but are already detected by palynology.

A long time period is necessary (hundreds of years) until woodland composition changes resulting from farming/herding activities become visible. The increase in demography, the technological developments and changes in cultural practices are most certainly implicated in this process.

During the Middle Neolithic, changes in the proportion of dominant species (deciduous *Quercus*, evergreen *Quercus*, *Olea*, *Pinus halepensis*) are remarked everywhere. The development of species resistant to constant cuts must have favoured the vigorous growth of dense coppices. The multiplication of open areas resulted in the development of light-demanding species. Clearly, cycles of land exploitation, associating wood cutting, farming and herding, followed by woodland regeneration must have occurred. Although forest regeneration following abandonment are rarely documented, as only occupied sites provide archaeobotanical remains, these changes are still reversible. Coppiced/pollarded woods probably reverted to mature woods, as observed in the last 50 years.

From the Middle Neolithic onwards, the heterogeneity of environmental situations suggests a mosaic of landscapes and woodlands at different stages of maturity, according to the history of each region. Different explanations can be proposed for each case; the factors linked with climate and those linked with man interfere heavily.

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Chapter 7
Evidence for Early Crop Management Practices in the Western Mediterranean: Latest Data, New Developments and Future Perspectives

Guillem Pérez-Jordà, Leonor Peña-Chocarro, Jacob Morales Mateos, and Lydia Zapata

7.1 Introduction

The origins and spread of agriculture from Southwest Asia to Europe has been one of the key topics in archaeological research for the past 40 years. The number of papers, monographs and research projects devoted to the topic is enormous and major developments have been achieved leading to a better understanding of this major turning point in the history of mankind. The topics investigated are many (domestication, dispersal, wild progenitors, morphometric changes in cereals, climate change, social complexity, settlement patterns, harvesting technologies, storage, consumption, ritual practices, etc.) and the disciplines involved numerous (archaeobotany, genetics, chemistry, environmental sciences, biology, sociology, ethnography, etc). Plant remains have been, however, at the forefront of many of the developments achieved.

[†] At the time of submitting this paper our friend Lydia is not any more with us. This work is dedicated to her in gratitude for inspiring ideas, enthusiastic and generous support and friendship.

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In the Iberian Peninsula, research into the origins of agriculture started with some delay as archaeobotanical investigations did not properly begin until the 1980s. The earliest study of Neolithic plant remains goes back to the 1930s when the German researcher, Fritz Netolitzky (Netolizky 1935), analysed samples from Cueva de Los Murciélagos (Córdoba). During the second half of the twentieth century, Maria Hopf, a key figure in the development of archaeobotanical research in the Iberian Peninsula, studied the major Neolithic sites both in the País Valenciano (Cova de l'Or) and in Andalucía (Cueva de Los Murciélagos and Cueva de Nerja) (Hopf 1966, 1974; Hopf and Muñoz 1974; Hopf and Pellicer 1970; Hopf and Schubart 1965) identifying the first crops of Iberian Neolithic farmers. Her work was a major milestone in the development of studies on the origins of agriculture.

Since the 1980s, and particularly during the 1990s, an increasing interest towards archaeobotany has been in evidence, in greater attention on sampling and recovery techniques coupled with the training of, and has led to a better understanding of prehistoric plant use as a whole. The number of botanical assemblages has consequently enlarged and over the past years our knowledge of the origins of agriculture has greatly improved. Archaeobotanical research has been primarily conducted in those areas where the Neolithic was being intensively investigated. In fact, our work on Neolithic agriculture (Zapata et al. 2004) showed a concentration of studies along the eastern coast of the Iberian Peninsula where archaeological research had been developed. During the last decade a considerable effort has been made to improve our understanding of Neolithic expansion towards other Iberian areas, and so data on Neolithic agriculture has been acquired from new regions such as the Cantabric region (Peña-Chocarro 2012; Peña-Chocarro et al. 2005a, b; Zapata 2002, 2007), the north Castilian plateau (López García et al. 2003; Peña-Chocarro 2007; Stika 2005) or the southern part of the Iberian Peninsula (Buxó 1997; Cortés Sánchez et al. 2010, 2012; Peña-Chocarro 1999, 2007; Peña-Chocarro et al. 2013a; b; Peña-Chocarro and Zapata 2010, 2014; Pérez Jordà et al. 2011). Additionally, further research has been carried out in areas of Cataluña (Antolín 2016; Antolín and Buxó 2011, Antolín et al. 2013, 2014, 2015; Antolín and Jacomet 2015; Buxó 2007) and in the País Valenciano (Pérez Jordà 2005, 2006, 2013; Pérez Jordà and Peña-Chocarro 2013).

In 2008, in the context of this growth in research, funding was obtained from the European Research Council through an Advanced Grant (AGRIWESTMED, ERC-AdG 2008-230561) and from the Spanish Ministry of Science and Innovation (HAR2008-01920/HIST) to explore in depth the exploitation of the new domestic resources and the timing of adoption of the new subsistence system in the western Mediterranean with the aim of reaching a better understanding of the more general process of economic, cultural and social change.

The AGRIWESTMED project has approached the study of the arrival of agriculture to this region by exploring different interrelated research areas, and has involved the application of different techniques (analysis of charred plant remains, pollen and non-pollen palynomorphs, phytoliths, micro-wear analyses, isotopes, geoarchaeology, genetics, and ethnoarchaeology) in order to define the emergence and spread of agriculture in the area, its likely place of origin, its main technological attributes as well as the range crop husbandry practices carried out. Moreover, the overall aim has been to achieve a greater understanding of the type of agriculture that characterized the first farming communities in the most south-western part of Europe (Peña-Chocarro et al. 2013b).

The objectives of this project have been organized around a series of research questions aimed at:

- Characterizing the crop assemblage and associated weeds that defined Neolithic agriculture in this region.
- Investigating the agricultural technology of the first western Mediterranean farmers.
- Examining crop husbandry practices.
- Looking at the emergence of agriculture within a palaeoclimatic context and providing clues on climate conditions and sustainability at the beginnings of agriculture in relation to the adopted strategies for water management and the nutritional status of crops.
- Exploring the possible routes of arrival of the first cultivated plants to the Iberian Peninsula, determining their influence in the making of the first agriculture and later spread through the territory.
- Providing an accurate chronological framework for the emergence of agriculture in the western Mediterranean region.

This paper summarizes results from AGRIWESTMED focusing on the characterization of the first agriculture through the study of the available archaeobotanical data and including information from new sites. Detailed information is given on the particular features of the crop assemblages studied for each period including discussion on regional patterns. These are discussed within the context of crop diversity by exploring different issues that may have accounted for such variability. The paper draws attention to the different agricultural traditions encountered in the Iberian Peninsula during the Neolithic and explores contacts with other regions and possible routes of arrival.

7.2 Early Farming: Characterizing Crop Assemblages

Archaeobotanical data from the sixth millennium BC in the Iberian Peninsula comes from the areas of Cataluña, Valencia, Eastern Andalucía and the northern Meseta (Fig. 7.1). In other regions such as the Upper Ebro valley, Cantabric area or the Pyrenees, the archaeobotanical record is discontinuous although various studies are in progress and begin to be published (Rojo Guerra et al. 2015a, b). The situation does not improve for the fifth millennium BC being lower the number of sites where sampling has been carried out and poorer the quality of data retrieved.

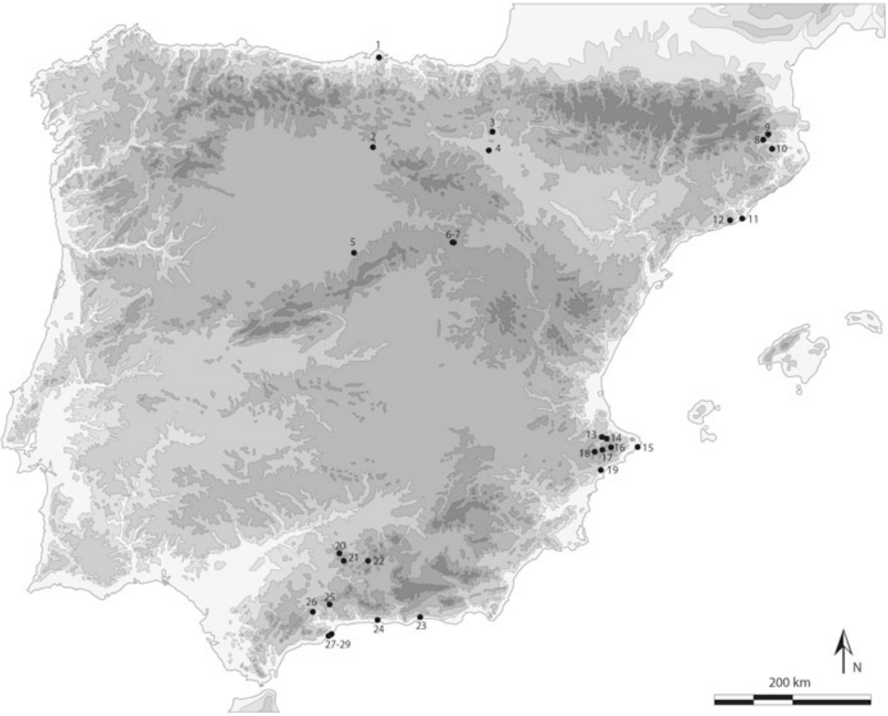

Fig. 7.1 Map showing the sites mentioned in the text. *1*. El Mirón, *2*. El Mirador, *3*. Cordovilla, *4*. Los Cascajos, *5*. La Vaquera, *6*. La Lámpara, *7*. La Revilla, *8*. Plansallosa, *9*. Cova 120, *10*. La Draga, *11*. Sant Pau, *12*. Can Sadurní, *13*. Cova de l'Or, *14*. Cova d'En Pardo, *15*. Cova de les Cendres, *16*. Coves de Santa Maira, *17*. Mas d'Is, *18*. Abric de La Falguera, *19*. Tossal de les Basses, *20*. Cueva de Los Murciélagos de Zuheros, *21*. Cueva de Los Mármoles, *22*. Los Castillejos de Montefrío, *23*. Cueva de Los Murciélagos de Albuñol, *24*. Cueva de Nerja, *25*. Cueva del Toro, *26*. La Higuera, *27*. Roca Chica, *28*. Bajondillo, *29*. Hostal Guadalupe

7.2.1 The Sixth Millennium cal BC

In Andalucía, most Early Neolithic archaeobotanical remains are dated to the second half of the sixth millennium (Fig. 7.2) and are concentrated at the sites of Los Castillejos de Montefrío in Granada (Rovira i Buendía 2007) and Los Murciélagos de Zuheros in Córdoba (Hopf 1974; Hopf and Muñoz 1974; López García 1980; Peña-Chocarro 1999; Pérez Jordà et al. 2011; Peña-Chocarro et al. 2013a). There are, however, smaller assemblages that come from caves in Córdoba province such as Los Mármoles de Priego (Carvalho et al. 2010; Cortés Sánchez et al. 2012; Peña-Chocarro et al. 2013a) and in Málaga province, sites in the Torremolinos area—Hostal Guadalupe, Cueva de Bajondillo and Cueva de Roca Chica (Peña-Chocarro and Zapata 2010; Pérez Jordà et al. 2011), Cueva de Nerja (Aura Tortosa et al. 2005), Cueva del Toro (Antequera) (Buxó 1997; Martín Socas et al. 2004) and La Higuera (Cádiz) (Peña-Chocarro and Zapata 2010; Espejo

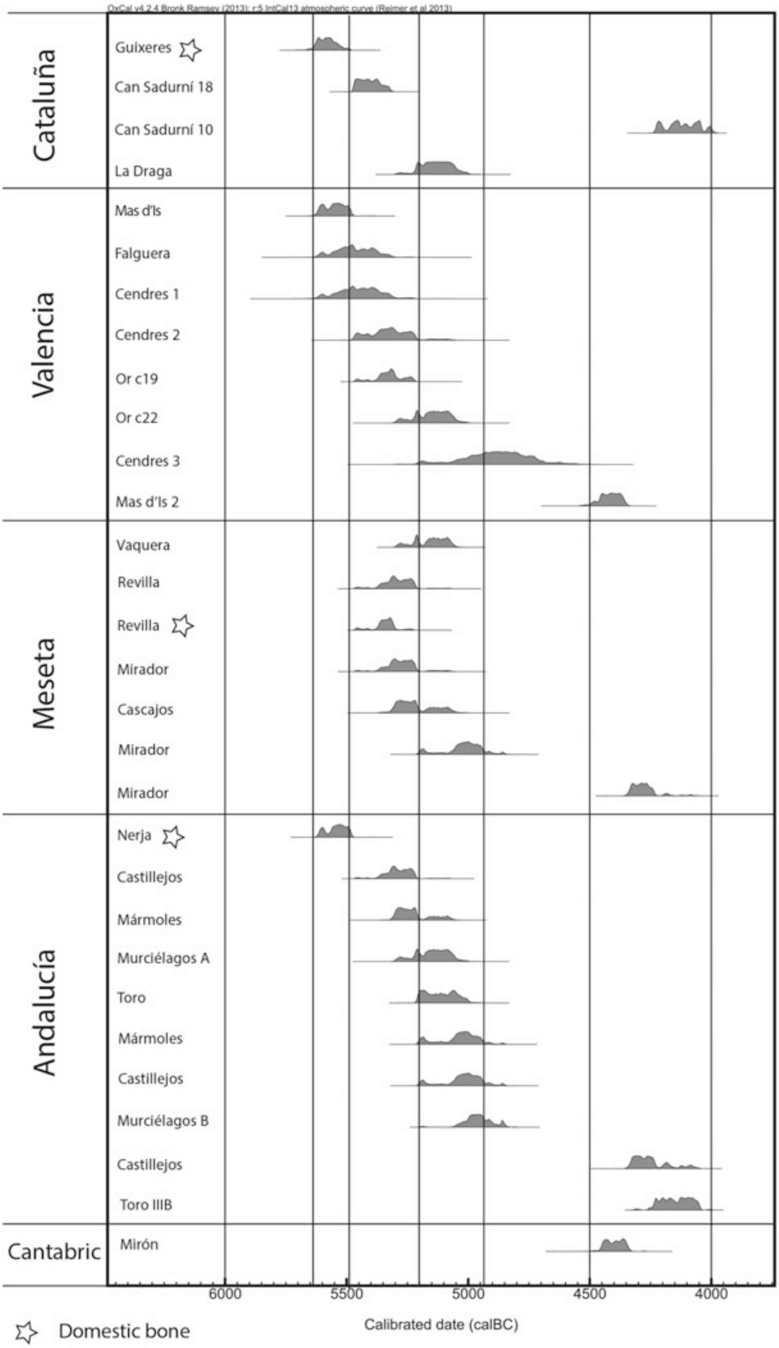

Fig. 7.2 Calibrated radiocarbon dates on cereal remains (*Star* = domesticated animal bone)

Herrerías et al. 2013). Archaeobotanical evidence has thus mainly been recovered from the upper part of the Guadalquivir Valley and the coast of Málaga while the rest of Andalucía is still largely unknown.

Although free-threshing wheats (*Triticum aestivum/durum*) and naked barley (*Hordeum vulgare* var. *nudum*) are the dominant species in the assemblages (Fig. 7.3), there are also differences between sites. At Los Castillejos and Los Mármoles, free-threshing wheats are dominant while at Los Murciélagos de Zuheros naked barley is the main species. In the area of Granada, the second most common cereal was einkorn (*Triticum monococcum*) while at sites in Córdoba, hulled barley (*Hordeum vulgare* subsp. *vulgare*) and emmer (*Triticum dicoccum*) were dominant suggesting some regional differences (Pérez Jordà et al. 2011).

According to the available data, both Andalucía and Valencia appear characterized by substantial crop diversity, although in Andalucía the ubiquity of hulled wheats was lower. Legumes are also common, particularly the pea (*Pisum sativum*). The presence of poppy (*Papaver sommniferum/setigerum*) appears as a characteristic of the territory of Andalucía. It is observed at Los Murciélagos de Zuheros and possibly at Los Castillejos de Montefrío where poppy is accompanied by flax (*Linum usitatissimum*).

In the País Valenciano (Table 7.1), the only samples that characterize the agriculture of the first farming communities were recovered during the excavation at Mas d'Is (Bernabeu Aubán et al. 2003; Pérez Jordà 2013). The assemblage contained a few remains which point to the presence of hulled barley, free-threshing wheats and einkorn. The majority of the evidence comes, however, from levels of a slightly later date, not earlier than 5450 cal BC. From then on, until the end of the sixth millennium cal BC, data from Cendres (Buxó 1997), Cova de l'Or (Hopf and Schubart 1965; Hopf 1966; Pérez Jordà 2013) (Fig. 7.3) and Abric de La Falguera (Pérez Jordà 2006) suggests that agriculture was clearly dominated by the cultivation of cereals and the presence of pulses.

In the larger caves, remains of wild fruits were rare while in those caves used as animal pens their presence is more important. Understanding the role of wild plants in the Neolithic subsistence economies is not an easy task. Recent work by Colledge and Conolly (2014) shows that taphonomic biases determine the preservation of plant remains in the archaeological context influencing the composition of the plant assemblages. The archaeobotanical record from other areas such as England (Jones 2000), Turkey (Fairbairn et al. 2007), south-east Europe (Marinova et al. 2013), northern Africa (Morales et al. 2013) or even the latest results from the northeastern Iberian Peninsula (Antolín and Jacomet 2015; Antolín et al. 2015) indicate that wild plants were part of the human diet although their contribution and their relative importance are still under discussion. In the case of the País Valenciano, the scarcity of wild plants may just be a reflection of their secondary role in the diet compared to cereals and pulses.

In the País Valenciano, agriculture appears dominated by the free-threshing wheats, except for the two earliest levels at Cova de les Cendres where emmer was the main species. The contribution of other cereals is varied. At Cova de l'Or

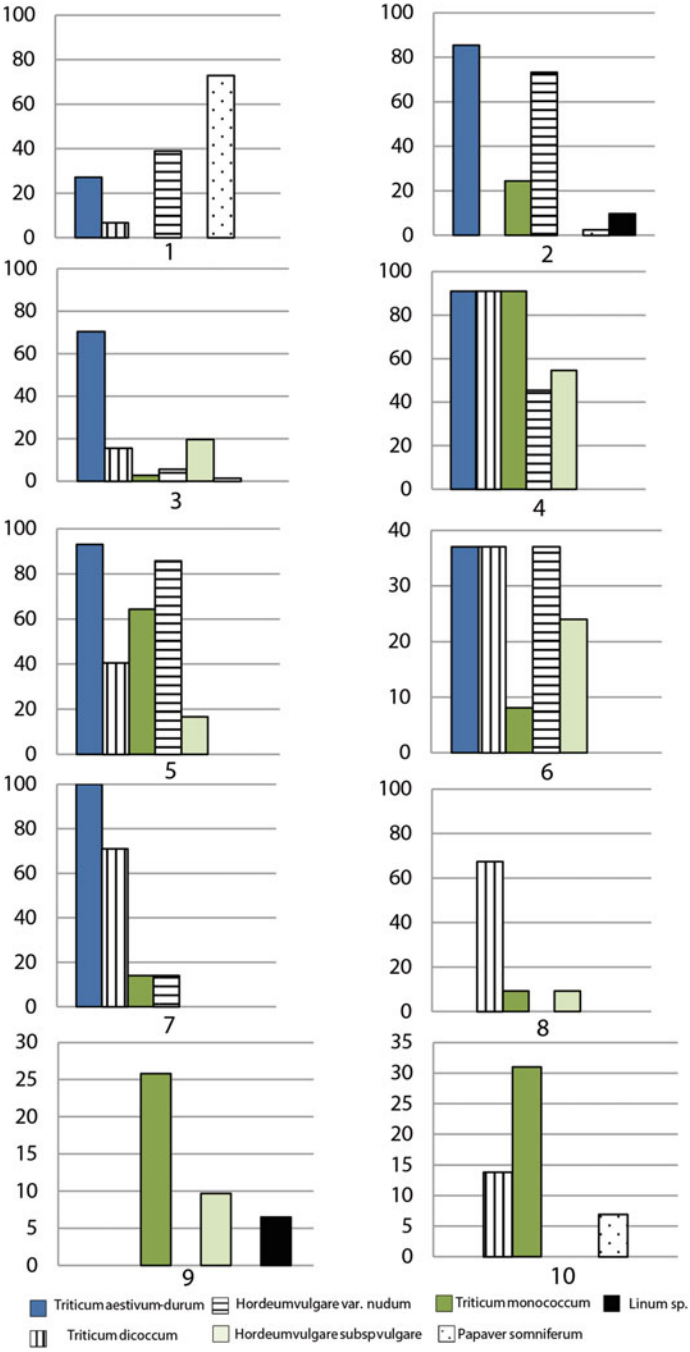

Fig. 7.3 Graph showing the ubiquity of the major crops during the sixth millennium cal BC. *1*. Los Murciélagos de Zuheros (phase A), *2*. Los Castillejos (levels 1–6), *3*. La Draga, *4*. Can Sadurní (levels 18–17), *5*. Cova de l'Or, *6*. Cova de les Cendres (levels IA–IB), *7*. Cueva del Mirador (levels 24–18), *8*. Los Cascajos, *9*. La Revilla, *10*. La Lámpara

Table 7.1 Crop plants recorded at sixth–fifth millennium cal BC sites of the Iberian Peninsula, f-fff = relative abundance of plant remains

			Cereals						Legumes						Oil plants	
			Triticum aestivum-durum	*Triticum durum*	*Triticum dicoccum*	*Triticum monococcum*	*Hordeum vulgare*	*Hordeum vulgare nudum*	*Pisum sativum*	*Lens culinaris*	*Vicia faba*	*Vicia ervilia*	*Vicia sativa*	*Lathyrus cicera/ sativus*	*Linum usitatissimum*	*Papaver setigerum/ somniferum*
		cal. BC aprox	Bread/hard wheat		Emmer	Einkorn	Hulled barley	Naked barley	Pea	Lentil	Faba bean	Bitter vetch	Common vetch	Grass pea	Flax	Poppy
Cataluña	Can Sadurní	5470–5300	ff		fff	f	f	f								
	La Draga	5300–5000	fff	f	f	f	ff	f	f		f					fff
	Plansallosa	5300–5000	f				f	f								
	Sant Pau	5300–5000	ff		f		fff	f	f		f	f				
	Cova 120	4500	fff		f		ff	ff								
	Camp del Colomer	4500–4200	f		f	f		fff	f			f			f	f
País Valenciano	Mas d'Is (VI)	5600–5500	fff			f	f									
	Falguera	5600–5300	fff		f	ff	f	f		f						
	Cendres	5500–5000	fff		ff	f	f	f	f	f	f			f		
	Cova de l'Or	5400–5000	fff		f	ff	f	ff								
	Cendres	5000–4500	ff		f	f	ff	fff				f				
	Mas d'Is (Vb)	4500–4300	ff					fff								
	Santa Maira	4500–4000	fff				f	ff	f	f			ff	f		

Andalucía	Los Castillejos	5300–5000	fff		f	ff	f	fff	f		f				f	f
	Nerja	5200–5000	f					f								
	Los Murciélagos de Zuheros	5300–5000	fff	f	ff	f	f	fff	f	f			f			fff
	Los Mármoles	5300–5000	fff	f	ff	f		f	f		f					
	Hostal Guadalupe	5300–5000	fff													
	Bajondillo	5200–5000	fff													
	Roca Chica	5300–5000	f		f		f	fff								
	La Higuera	5300–5000						fff	f		f					
	Cueva del Toro (IV)	5200–5000	fff					fff		ff	f			f		
	Cueva delToro (IIIb)	4250–4000	fff				f	fff		f	ff					
Meseta	La Lámpara	5300–5000			fff	fff	f									f
	La Revilla	5300–5000			f	fff	f								f	
	LaVaquera	5300–5200	f		f		f									
	Los Cascajos	5300–5000			fff	f	ff									
	El Mirador (1)	5300–4900	ff		fff	f		f								
	El Mirador (2)	4400–3800	fff					f	f						f	
Cantábrico	El Mirón	4500–4300	fff		f	f										

naked barley was clearly the second most important crop together with einkorn, while emmer and hulled barley were rare. At Abric de La Falguera, naked and hulled barley along with emmer were less common, while einkorn was the second-most important crop. The situation at Cova de les Cendres was more variable, free-threshing wheats, emmer and naked barley are secondary crops and hulled barley has a more significant role while einkorn was rare. Evidence suggests a tendency towards a progressive increase in free-threshing wheats and naked barley, with a corresponding decline in hulled wheats. This points to a shift from agricultural diversity to the establishment of cereal cultivation clearly based on two main crops.

The available archaeobotanical evidence for the northern Meseta (Table 7.1) is concentrated in the area of Ambrona (Soria), more specifically at the sites of La Revilla and La Lámpara (Rojo Guerra 2008; Stika 2005). The predominance of hulled wheats stands out, in particular einkorn, while barley was rare and free-threshing wheats and naked barley were absent. Poppy and flax were also present (Fig. 7.3).

The cave of El Mirador (Rodríguez Cruz et al. 2016; Vergès Bosch et al. 2008) in Burgos province has a rich archaeobotanical record (Table 7.1). Depending on the stratigraphic levels, either emmer or free-threshing wheats were predominant, while both naked barley and einkorn were rare. Legumes were also poorly represented and it was often difficult to identify them even to genus level. At the cave of La Vaquera (López García et al. 2003), the evidence from phase IA (the earliest Neolithic level) was limited, but did suggest a predominance of free-threshing wheats, along with lower levels of hulled wheats and barley. For the area of Navarra the only available evidence so far is from the site of Los Cascajos (García Gazólaz and Sesma Sesma 2001; Peña-Chocarro et al. 2005a), where emmer and possibly einkorn, along with hulled barley, were documented. *Triticum dicoccum* was the most important crop while the remaining species were rare.

The earliest (late sixth–early fifth millennia BC) evidence from the northern Meseta and Navarra (Fig. 7.3) shows a very different scenario compared to the rest of the Iberian Peninsula. On the one hand, there are sites such as Los Cascajos and those in the Ambrona valley which are exceptional since they are the only cases so far in which only hulled cereals were present. The Ambrona sites also contained evidence for two other crops, flax and poppy, both of which have variable distribution in the Iberian Peninsula. As has been argued by Stika (2005), this scheme is very similar to that found at central European LBK sites (Bogaard 2004; Kreuz 2007). On the other hand, free-threshing wheats were important at the sites of El Mirador and La Vaquera, very close to the Ambrona area, although hulled cereals were also present.

In Cataluña (Table 7.1), the most representative assemblages are from Can Sadurní (Antolín 2016; Antolín et al. 2013) and La Draga (Antolín and Buxó 2011; Antolín 2016; Antolín et al. 2014). At Can Sadurní site (Fig. 7.3), all three wheat types were present in similar proportions although in terms of the number of remains, *Triticum dicoccum* was the most abundant, followed by *Triticum aestivum/durum* and *Triticum monococcum*. Barley was less important overall, with the naked form predominant. At La Draga, free-threshing wheats, probably *Triticum* *durum,* were predominant both in frequency and number of remains. In fact, it is suggested that agricultural production was mainly based on the cultivation of this type of wheat. From the remaining cereals only hulled barley is quite frequent occurring at times in small concentrations, while the importance of naked barley is much lower. As for the hulled wheats, the frequency of *Triticum dicoccum* is quite high while the values of *Triticum monococcum* are lower, although in both cases the number of remains is small. Legumes represented by fava beans and peas are rare. In previous studies doubts were expressed regarding the cultivation of poppy (Antolín and Buxó 2011); however, the importance of this crop for the community has recently been confirmed by Antolín (2016) and Antolín et al. (2015).

Around these sites, assemblages from other settlements have been studied allowing for a territorial scale assessment of early agriculture. In the site of Plansallosa (Bosch et al. 1998) located in the north-eastern part of Cataluña, close to La Draga, free-threshing wheats together with hulled barley are the main cereal species (Table 7.1). A greater diversity and a more important role of emmer is found at the estuary of the river Llobregat, an area close to Can Sadurní, where the sites of Can Tintorer (Buxó et al. 1991) and Sant Pau (Buxó and Canal 2008) are found.

In general, the record from the Iberian Peninsula is varied. The archaeobotanical evidence is quite uniform, and with the exception of the sites of Ambrona and Los Cascajos, considerable numbers of cereal crops are documented. In this diverse record, free-threshing wheats usually predominate, with an increasing tendency in those areas for which information exists. Exceptions to this general trend include the early phases of occupation at Cova de les Cendres, Can Sadurní and some phases of El Mirador where *Triticum dicoccum* plays an important role (Fig. 7.3). Another factor that characterizes Andalucía and the País Valenciano is the importance of naked barley, which is documented neither in Cataluña nor in the interior of the peninsula. Legumes are not a differentiating element. They are represented in most areas although the record is less prominent in the Meseta. A special characteristic relates to the presence of two frequent crops in central Europe, poppy and flax, which in the Iberian Peninsula appear mainly in inland areas, both in the northern part of the Meseta and in Andalucía. This peculiarity of the Iberian archaeobotanical record requires further investigation in order to explore possible contacts between these regions which could explain their similarity.

7.2.2 The Fifth Millennium cal BC

The archaeobotanical evidence for the fifth millennium (Table 7.1) is scarcer than for the sixth. In Andalucía (Fig. 7.4), phases 7–11 of Los Castillejos together with Cueva de Los Murciélagos de Zuheros, and Cueva de Los Murciélagos de Albuñol provide archaeobotanical data for the beginning of the millennium. There is then a major gap in the record which lasts until the end of the fifth and beginnings of the

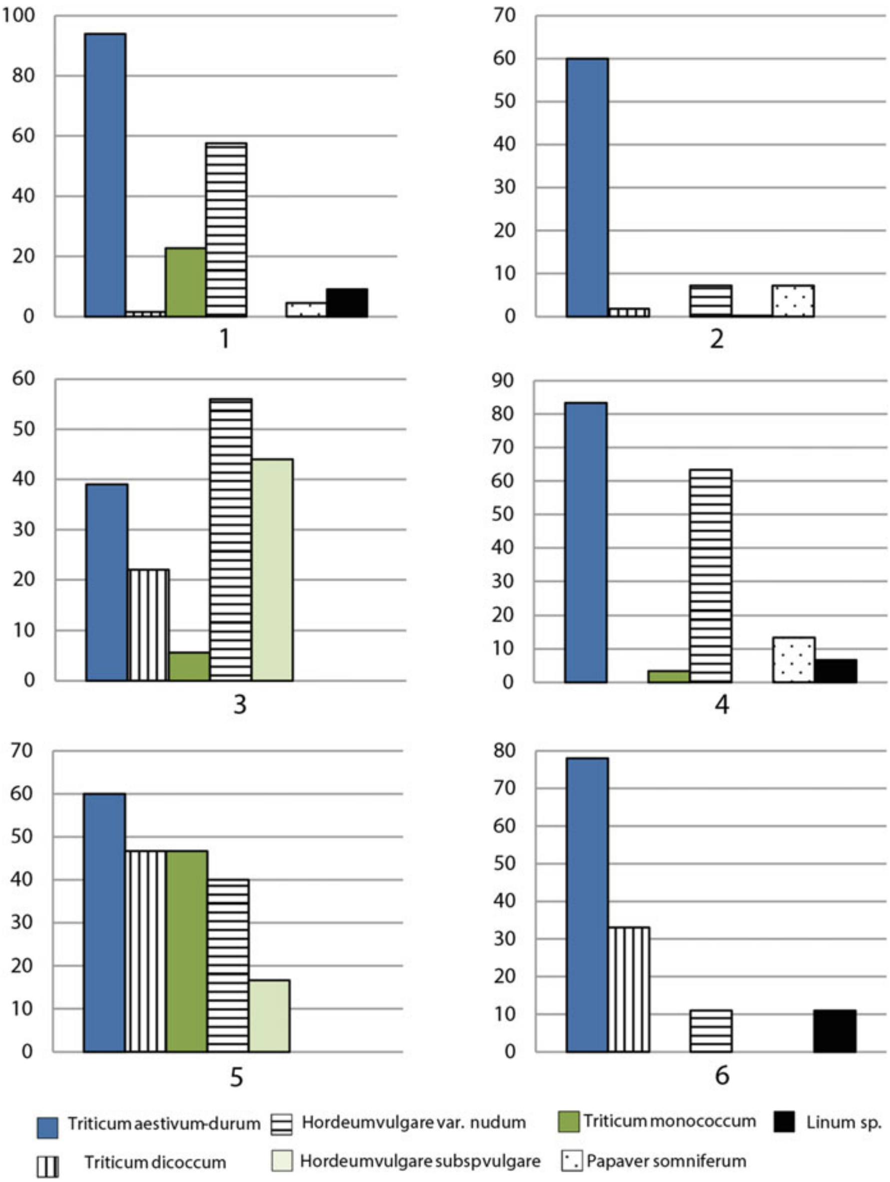

Fig. 7.4 Graph showing the ubiquity of the major crops during the fifth millennium cal BC. *1*. Los Castillejos (levels 7–11), *2*. Los Murciélagos de Zuheros (phase b), *3*. Cendres (level IC), *4*. Los Castillejos (levels 12–14), *5*. Can Sadurní (levels 11–10), *6*. Cueva del Mirador

fourth millennia. The major sites belonging to this period are: phases 12–14 from Los Castillejos (Rovira i Buendía 2007), phase IIIb from El Toro (Buxó 1997; Martín Socas et al. 2004) and the pit of Nerja (Hopf 1991; Hopf and Pellicer 1970; Pérez Jordà et al. 2011; Peña-Chocarro et al. 2013a).

Cereal crops and, in particular, free-threshing wheats and naked barley dominate all phases at Los Castillejos and show an increasing tendency. Einkorn had low and irregular percentages while emmer was documented only in phase 9. Legumes followed with percentages fluctuating between 16 and 5%, but without a clear tendency. However, their importance was in general greater compared to the previous phase. Fava beans and peas were the most significant species, the latter being more abundant. Furthermore, crops such as flax also increased (Rovira i Buendía 2007).

The evidence from the Cueva de los Murciélagos de Zuheros (Peña-Chocarro et al. 2013a; Peña-Chocarro 1999) points to similar values. Free-threshing wheats and naked barley were the most important crops while hulled barley and emmer were in decline. Poppy was still present although its values were slightly lower compared to the previous phase.

The site of Los Murciélagos de Albuñol (Cacho Quesada et al. 1996) provides a further assemblage partly dated to the transition between the sixth and fifth millennia, along with other fifth millennium dates. Poppy capsules were recorded inside some esparto-grass baskets that were part of the burials, highlighting the importance of this species in Andalucía since prehistoric times.

The site of Los Castillejos (Rovira i Buendía 2007) provides rich evidence for the end of the fifth and early fourth millennia. Cereals prevailed between phases 12 and 14 while other species such as flax increased compared to previous periods. Free-threshing wheats were dominant compared to naked barley while other cereal species such as einkorn became marginal from this time onwards. Amongst the legumes *Lathyrus sativus* was identified for the first time, although peas and fava beans were still predominant, the latter with an increasing tendency during the final phase.

The situation was similar in level IIIb at Cueva del Toro (Buxó 1997), where free-threshing wheats prevailed over naked barley. Conversely, hulled barley was rare while hulled wheats were absent. Lentils were more common than fava beans.

In the País Valenciano (Fig. 7.4), only the site of Cova de les Cendres (Buxó 1997) produced an assemblage of sufficient size to allow the characterization of agriculture during the first half of the fifth millennium cal BC. The pattern was very similar to that present towards the end of the sixth millennium, with high percentages of free-threshing wheats and hulled barley, along with small quantities of hulled wheats. At the three other sites in the region, Tossal de les Basses, Cova d'En Pardo and Mas d'Is (Pérez Jordà 2013), only the three main crops were recorded suggesting a tendency towards the consolidation of free-threshing cereals and a reduction in hulled wheats, along with the continuous presence of hulled barley, particularly along the coastal zone.

The second half of the millennium is also poorly documented (Pérez Jordà 2013). Only Les Coves de Santa Maira and the phase Vb of Mas d'Is (Table 7.1), both sites located in the interior, provided considerable quantities of material. Free-threshing wheats and naked barley were present in similar proportions, as well as a rich assemblage of legumes (lentils, peas and grass pea). By now, the shift towards the predominance of naked cereals, which began around the end of the sixth millennium, has been fully achieved and the agricultural system is exclusively based on the cultivation of the two dominant crops, free-threshing wheats and naked barley, while hulled cereals (wheat and barley) are absent.

The only evidence from the Meseta (Table 7.1) comes from phase 2 of El Mirador (Rodríguez Cruz et al.2016; Vergès Bosch et al. 2008) and phase II of La Vaquera (López García et al. 2003) where free-threshing wheats were the prominent crops (Fig. 7.4). Emmer at El Mirador and naked barley of La Vaquera were also important, while hulled barley and einkorn were rare. Recently, material from the site of Cordovilla (Navarra) has been analyzed, from which an assemblage containing *Triticum monococcum* dated to the mid-fifth millennium has been documented (on-going research by the authors).

In Cantabria, plant remains from El Mirón (Table 7.1) (Peña-Chocarro et al. 2005b; Peña-Chocarro 2012) point to the presence of both free-threshing and hulled wheats, but unfortunately without an evaluation of the contribution of each.

In Cataluña, the best evidence available comes from levels 11 and 10 of Cova de Can Sadurní (Antolín 2016), dated to the second half of the fifth millennium (Table 7.1). The results from these two levels were quite different, while free-threshing wheats, followed by similar proportions of the other four cereals, prevailed in layer 11, level 10 was characterized by the presence of hulled wheats and to a lesser extent of free-threshing wheats and barley (Fig. 7.4). Hulled barley was absent. The most common legumes were lentil, pea and vetch (*Vicia sativa*). In Cova 120 (Agustí et al. 1987), the presence of free-threshing wheats is highlighted. In addition, hulled and naked barley are also documented and there is a limited presence of emmer.

Figure 7.4 represents the pattern of species distribution. Except for Cataluña, the predominant species were free-threshing wheats and naked barley. Andalucía and the País Valenciano followed the same trajectory with free-threshing wheats established as staple crops, while hulled wheats progressively declined in importance. Some discrepancy is noted in the ubiquity of hulled barley in the País Valenciano. Looking at the sites in the northern part of inner Iberia, the only difference amongst sites relates to the relative importance of hulled wheats. Although the picture from the Iberian Peninsula during the fifth millennium is not uniform, the evidence shows a general trend towards a decrease of diversification compared to the previous millennium.

7.3 Neolithic Crop Diversity

Crop diversity is a common practice in farming societies where agricultural production is oriented towards self-sufficiency. It represents one of the buffering mechanisms to cope with uncertainty and unpredictable climatic fluctuations. Diversification may be practiced by growing different crops minimizing shortfalls and variability in the harvest. A further measure against environmental changes may include planting crops in different locations lessening the risk of crop failure (Peña-Chocarro and Zapata 2014). Particular species or even varieties may have been adapted to the specific characteristics of a particular area. Crops are limited by a series of geographical factors (altitude, temperature, humidity, sun exposure, etc.) and, therefore, environmental constraints are key for understanding not only what factors may have caused variations in the climatic conditions and, as a consequence, increased uncertainty, but also what particular crop or array of crops is chosen by a particular human group. Besides, cultural and social issues may have also contributed to crop diversity.

Based on the wide variety of cereal crops, legumes together with the contribution of some oil plants, Iberian agriculture has been always described as one of the most diverse of the whole of Europe (Zapata et al. 2004; Hopf and Schubart 1965; Hopf 1966). However, it is fair to recognize that comparison has been always made against the situation observed in central European sites (Kreuz et al. 2005) and that the important similarities between Iberia and Italy have been little stressed (Rottoli and Castiglioni 2009).

The Iberian archaeobotanical record for the Neolithic includes five cereal taxa, six legumes and two oil plants (Fig. 7.5) which appear in variable proportions in the different area. As discussed earlier, the highest diversity in both cereals and legumes occurs along the eastern fringe and in the southern half of the Iberian Peninsula. In most cases, the evidence points to a predominance of one or two crops amongst the cereals, while the contribution of the remaining species is not significant. It seems that some staples were initially selected and then maintained through time.

Exploring the reasons for such diversity is a difficult task but several factors may have accounted for it whether in a conscious or unconscious way. It is yet unclear whether this diversity reflects a deliberate strategy practiced by early farmers or if environmental issues may have also influenced the selection of certain crops or combinations of crops. For instance, sites in inner Iberia such as those in the Ambrona valley or Los Cascajos in the Ebro Valley show a clear prevalence of hulled cereals. Given the particular location of these sites at a certain altitude in a rather cold area, it could be that hulled wheats were chosen for their adaptability to harsh conditions. However, in the same area, at other sites such as La Vaquera or Cueva del Mirador (at some levels), free-threshing wheats are the commonest cereal species. Naked wheats are also found in the coastal zone and in the southern part of the peninsula, but in these areas there are also variations. For instance, while in Can Sadurní and at the earliest levels of Cova de les Cendres, hulled wheats are the main crop, naked wheats and barley predominate in most of the settlements.

Fig. 7.5 Species present in the plant assemblages: (**a**) *Triticum monococcum*, grain; (**b**) *T. monococcum*, spikelet fork; (**c**) *Triticum dicoccum*, grain; (**d**) *T. dicoccum*, spikelet fork; (**e**). *Triticum aestivum*/*durum*, grain; (**f**) *T. durum*, rachis segment; (**g**) *Hordeum vulgare* var. *nudum*, grain; (**h**) *H. vulgare* var. *nudum*, rachis segment; (**i**) *Lens culinaris*, seed; (**j**) *Vicia faba*, seed; (**k**) *Pisum sativum*, seed; (**l**) *Lathryus* sp., seed; ll. *Linum usitatissimum*, seed; (**m**) *Papaver setigerum*/*somniferum*, seed. Scale = 1 mm

Some sites show different scenarios across time. Thus, as already stated, the earliest phases of sites such as Cueva del Mirador o Cova de les Cendres were dominated by hulled wheats, and towards the end of the sixth millennium cal BC free-threshing wheats outnumbered the remaining species. In neither of these sites is there data to support a big change in the environmental conditions that could explain this replacement.

Thus, we suggest that although environmental issues related to climate or soil types could have had an impact on the selection of crops by different communities, there were other more significant factors which would explain the nature and extent of this diversity. These include possible routes of arrival of the first groups of farmers that need to be evaluated as the origin of the differences observed.

7.4 Routes of Arrival

Based on the study of ceramic collections, there is evidence of the existence of different cultural traditions during the first phase of establishment of the Neolithic communities in the Iberian Peninsula. The pottery suggests a connection with groups within the sphere of influence of the Italian *impresso* wares (Maggi 2002), previously identified in southern France (Manen 2000; Binder and Maggi 2001; Guilaine et al. 2007; Guilaine and Manen 2007) and mainly represented in the Iberian Peninsula by assemblages located south of the gulf of Valencia (Bernabeu Aubán et al. 2009). Other elements in Andalucía and the País Valenciano also suggest relationships with the south of Italy and Sicily, reviving the idea of a possible neolithization of the Iberian Peninsula from North Africa (García Borja et al. 2010; Manen et al. 2007; Bernabeu Aubán et al. 2009). A further tradition, the Cardial, entered Iberia from the south of France (Manen 2002) and occupied a large part of the eastern coastal fringe of the Peninsula and the south of Portugal. The limitations of the current evidence (Oms et al. 2014; Bernabeu Aubán et al. 2009; Aura Tortosa et al. 2005), make it difficult to confirm the contemporaneity of these traditions.

After the establishment of these pioneer communities, two groups can be differentiated, the first, in Andalucía, is characterized by impressed and "a la Almagra" (red ochre decorated) pottery (García Borja et al. 2014). The second, in the northern interior of the peninsula, appears associated with impressed and *boquique* wares (García Martínez de Lagrán et al. 2011; Alday and Moral 2011).

In the context of the available archaeobotanical data, the comparison of regional traditions in the Iberian Peninsula is not yet possible but some of the observed trends can be discussed (Fig. 7.6). The earliest assemblage of plant remains which has delivered dates around 5550 BC is that of Mas d'Is which provided a rather limited collection of plants. Although evidence is still of limited quality, hulled wheats in these early phases appear to have had a more significant role than in later periods. This trend is better defined in the early levels of Can Sadurní and Cova de les Cendres, both dated to around 5500–5400 BC. In the south of France, the

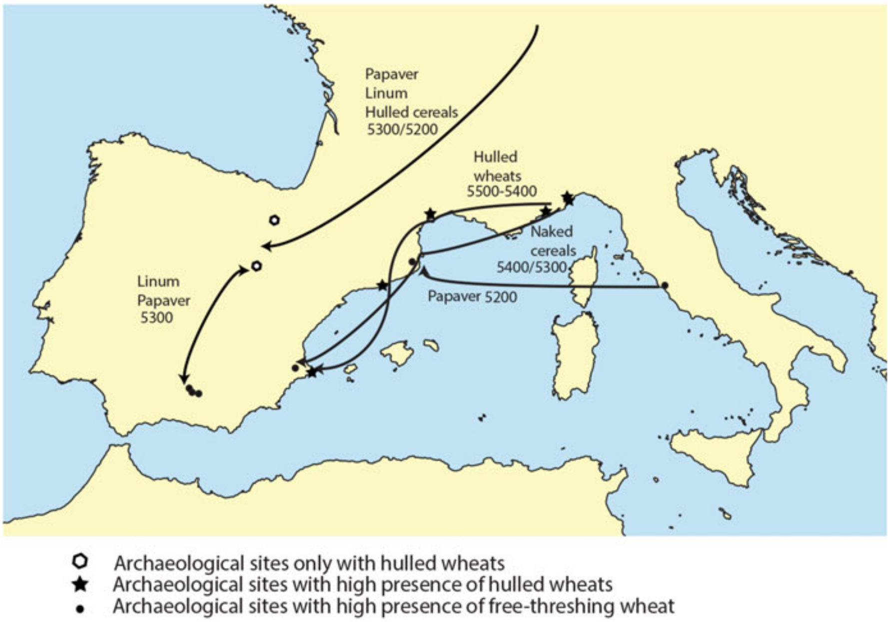

Fig. 7.6 Map showing hypothetical routes of agriculture spread in the Iberian Peninsula

archaeobotanical record of the *impressa* facies (Pendimoun, Roque-Haute and Peiro Signado) is characterized by the predominance of hulled wheats, while in the later cardial levels free-threshing wheats and naked barley were more common (Gassin et al. 2010). As for the *impressa* facies from Liguria, a similar trend is suggested by the evidence available from sites such as Arene Candide (Nisbert 2008) and San Sebastiano di Perti (Arobba and Caramiello 2006).

These elements have been used to suggest that the group which settled at the estuary of the Llobregat River, around Can Sadurní, had contacts to those belonging to the *Impresso* area (Antolín 2016; Antolín et al. 2015) and the same could also be proposed for the initial levels of Cova de les Cendres. However, it should be emphasized that the dates provided by these caves are later than those from the south of France and that their pottery is classified within the context of the classical Cardial (Bernabeu Aubán and Molina Balaguer 2009; Blasco et al. 2005). It remains to be explored whether an earlier system of agriculture continued in some points along the Mediterranean coast of Iberia, while at the same time in southern France hulled wheats had already been replaced by free-threshing cereals. Such a change occurred in the Iberian Peninsula around 5300 BC and is visible at Cova de l'Or, later phases of Cova de les Cendres, basal levels of Los Castillejos de Montefrío and within the caves of Los Mármoles and Los Murciélagos de Zuheros, where although hulled wheats were present, naked cereals were predominant.

At the same time, by 5300 BC, a new agricultural tradition associated with impressed and *boquique* wares, different from that developed along the

Mediterranean coast, emerges in the northern interior of the Iberian Peninsula. In fact the evidence from settlements in the Ambrona valley shows many features typical of the central European archaeobotanical record, and so the plant assemblage from sites such as La Lámpara and La Revilla (Stika 2005) is dominated by the presence of hulled wheats, flax and poppy. This is also the case of sites such as Los Cascajos, further north in the Upper Ebro Valley. What is more, these similarities are not restricted to the archaeobotanical dataset and have recently been shown to include other elements of the archaeological record such as types of settlements, inhumation rituals and material culture (García Borja et al. 2014). The lower levels of the Cueva del Mirador in the Sierra of Atapuerca do also show similarities with the central European area. While hulled wheats have a significant role in the archaeobotanical record, there are also many elements which are distinctive of the Mediterranean world. It is clear that this region was not at all homogeneous and it is likely that different traditions, still to be defined, coexisted. Attempts to draw possible connections between some of these sites and those within the central European area is made difficult by the general lack of archaeobotanical data for much of the interior of France. It is hoped that future investigation in this area will help to explore further the connections between the settlements mentioned above.

The uneven distribution of flax and poppy within the Iberian Peninsula provides another way in which contacts between different areas of Iberia can be investigated. While both species are almost absent from the most intensively sampled area, the Mediterranean, in the Guadalquivir valley and in the Ambrona valley both are detected in assemblages dating to after 5.300 BC. In terms of cereal cultivation, these areas are quite different, although there are similarities in the archaeobotanical evidence and some pottery elements which suggest links (García Borja et al. 2014). Since there are significant differences in the crops developed by groups in these two areas, it is thought that more than having a common origin, it is likely that both areas maintained contacts. Another important site in which poppy has been documented, although at slightly later date (6179 ± 39 BP), is La Draga, where the so-called "new" glume wheat is documented (Antolín 2016; Antolín et al. 2015). Both elements (presence of poppy and of the "new" glume wheat) suggest connections with central and northern Italy (Rottoli 1993; Rottoli and Castiglioni 2009).

The details outlined for the various regions under discussion show that an assessment of possible routes of arrival and of contacts between the different farming communities of the Iberian Peninsula can be explored on the basis of the archaeobotanical record of fruits and seeds (Fig. 7.6). Together with pottery, lithics and animal husbandry, crops are an additional important element for the cultural identity of groups. Since we are dealing with farmers, it is likely that the selection and management of crops were significant elements of the traditions and identity of the various farming communities.

7.5 The Evolution of Neolithic Communities

Human groups that establish themselves in a given territory, assuming they thrive and the population grows, will tend to expand into adjacent areas. For the early Neolithic phase Halstead (1989) proposed a model of agricultural exploitation for Thessaly in Greece which has also been suggested for the central European area by Bogaard (2004). The model is of an intensive agricultural or horticultural system, based on continuous cultivation of small plots located near water channels where the soil is richer, with the possibility for systematic manuring and where a range of taxa are cultivated, both cereals and pulses (Pérez Jordà and Peña-Chocarro 2013; Bernabeu Aubán et al. 1995; Antolín 2016; Antolín et al. 2015). This system does not allow for the growth of the groups, which are limited in part by the size of the area with similar soil able to be cultivated in this way. If the group manages to grow, this system results in a process of continuous creation of new small communities (García Borja et al. 2011).

In certain areas of the Iberian Peninsula it is possible to observe the evolution of some of these communities within their territories. One such example is the Serpis Valley in the interior of the País Valenciano. The pattern observed in different settlements located at the head of the valley, such as Cova de l'Or, Abric de La Falguera and Mas d'Is, is characterized by the predominance of free-threshing wheats, the selection of einkorn from the hulled wheats, the reduced role of hulled barley and the rarity of pulses. In the coastal zone at the site of Cova de les Cendres, the predominance of free-threshing wheats is not always evident, although the most prominent differences include the selection of emmer from the hulled wheats, higher frequencies of hulled barley and a more important role for pulses. Although it is true that the evidence is still scarce and it would be unwise to try and read too much into the results so far in terms of substantive difference between these two areas, other studies have also emphasized this divergence, for instance, on the basis of pottery (García Borja et al. 2011).

The evidence from the interior of Andalucía also highlights differences amongst the three settlements that have produced larger assemblages. In terms of the major crops, all three sites were similar although they differed in regard to secondary crop species. At Castillejos de Montefrío, einkorn stands out while both flax and poppy were also present. At Cueva de los Murciélagos de Zuheros, *Triticum dicoccum* was a secondary crop while of the oil plants only poppy was present. At Cueva de los Mármoles, it was again einkorn that was predominant. More data from other sites that could relate to the same community would be needed in order to clearly evaluate the differences between the territories.

In Cataluña, some territorial differences are also observed. Sites located around the mouth of the Llobregat River such as Can Sadurní, Can Tintorer and Sant Pau had higher crop diversity along with a predominance of hulled wheats. In the region of Empordà at sites such as La Draga and Plansallosa, free-threshing wheats were predominant while hulled barley was also an important crop.

On the basis of the current evidence and mindful of its biases, it is possible to suggest that each of these communities developed and applied broadly similar agricultural strategies, which can be interpreted as part of the group's overall identity. By the term community we do not here refer to all the individuals of each settlement, but to those who in a presumably coordinated way were integrated in a social organization of superior rank and occupied the different settlements of the territory.

The evidence currently available allows us to investigate the evolution of these communities during the sixth and early fifth millennia cal BC. There was a general tendency towards a reduction in diversity, mainly apparent in the decline of hulled wheats and consolidation of the two crops which became predominant, the free-threshing cereals (wheat and barley). Unfortunately from this point onwards the quality of the evidence deteriorates, particularly from the first half of the fifth millennium, limiting the detail in which we can approach the evolution of agriculture. In some territories, alongside the consolidation of the two free-threshing cereals, some of the traditional crops of the area were also maintained. For example, hulled barley in the coastal zone of the País Valenciano, flax and poppy in the interior of Andalucía, hulled wheats in the northern interior and einkorn in Can Sadurní. Some of these examples suggest that some crops were deeply embedded within the traditions of specific territories.

The reduction in agricultural diversity has been linked to a possible change in the agrarian model. It has been suggested that in the País Valenciano at some point during the fifth millennium cal BC, there was a shift from an intensive to extensive model, which is connected to the use of the plough (Pérez Jordà and Peña-Chocarro 2013). Although there is no evidence from weeds that would allow us to infer this change in the production model, various other elements that may reflect this shift have been interpreted alongside the archaeobotanical record.

Wood charcoal (Badal García et al. 1994) and pollen (López Sáez et al. 2011; Jalut et al. 2000) studies indicate the opening-up of woodland from the beginning of the fifth millennium cal BC. Similarly, sedimentological studies (Ferrer García 2011) point to the presence of short arid events associated with marked seasonal precipitation. It is not known whether the concentration of previously dispersed small village communities into larger centres with large grain storage facilities in silos, was related to changes in environmental conditions or some other variety of factors (Jover Maestre et al. 2011). Such a concentration of population makes the maintenance of intensive agriculture non-viable, at least as the only means of production. The way to increase output is to shift towards a more extensive system (Van der Veen and O'Connor 1998), by exploiting larger areas with the help of the plough. Even though the yield per unit area is lower, a larger volume of grain can be obtained. Such a change in the exploitation model may possibly explain the movement of animal herds outside of the settlement, at least for part of the year. This resulted in an increased use of caves as animal pens (Badal García and Martí Oliver 2011), and in an attempt to avoid damage to cultivated area which had been extensively expanded (Seguí 1999).

Despite important territorial and chronological gaps in the current evidence, the ideas presented in this study highlight advances in research since M. Hopf (Hopf and Schubart 1965; Hopf 1966) carried out initial investigations at Cova de l'Or. In a way, as archaeobotanists, we have failed to convince the archaeological community of the importance of systematically developing studies of this kind, which is particularly unfortunate when they relate to the first farmers in the Iberian Peninsula. We expect that the completion of a number of studies that are in progress and the new data that these will provide, together with the introduction of new technologies, will allow for a better understanding of the agricultural activities of these early communities.

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Chapter 8
Farming Practices in the Early Neolithic According to Agricultural Tools: Evidence from La Draga Site (Northeastern Iberia)

Xavier Terradas, Raquel Piqué, Antoni Palomo, Ferran Antolín, Oriol López, Jordi Revelles, and Ramon Buxó

Many Neolithic settlements are found in wetland locations, on the shores of lakes, lagoons or marshes but close to agricultural land. This pattern was recurrent at Early Neolithic sites in Southern Europe (Guilaine et al. 1984; Fugazzola et al. 1993; Rojo et al. 2008; Karkanas et al. 2011). In some cases, proximity to those wet environments has contributed to the preservation of artefacts made of wood and other organic materials, as occurred at the site of La Draga, on the shoreline of Lake Banyoles (northeastern Iberia), but also at sites in other parts of Europe. The chief examples are the Neolithic sites on lakes in the Alps and Jura Mountains, although the oldest settlements known there date from the mid-fifth to the mid-fourth millennium cal BC (Pétrequin and Pétrequin 1988).

However no site enjoys the conditions found at La Draga; its chronology (5320–4980 cal BC, several centuries older than the Alpine sites) and the diversity of wooden elements and artefacts recovered there confer on this site a special status

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in understanding the strategies carried out in the exploitation of forest resources, technological carpentry skills and use of wooden implements in the daily subsistence activities of the first farming societies in the Western Mediterranean.

8.1 The Archaeological Site of La Draga

La Draga site has provided evidence of some of the earliest farming societies in open-air settlements in Northeastern Iberia, dated to the late sixth millennium cal BC (Bosch et al. 2011, 2012; Palomo et al. 2014). The site is on the eastern shore of Lake Banyoles, at 173 m asl, 35 km from the Mediterranean Sea and 50 km south of the Pyrenees (Fig. 8.1).

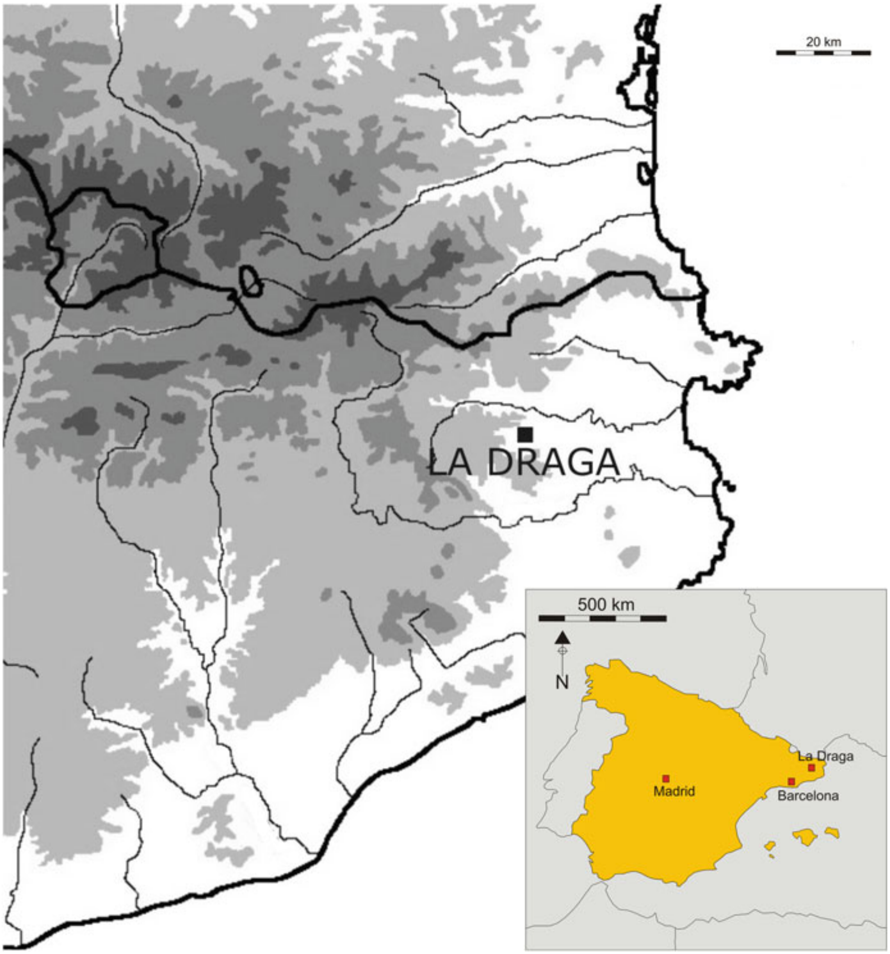

Fig. 8.1 Location of the site of La Draga (Banyoles, northeastern Iberia)

Following its discovery in 1990, excavation has been undertaken at this site during multiple field seasons from 1991 to the present. The first work, initiated under the coordination of the Archaeological Museum of Banyoles, was halted in 2005 in order to finalise the scientific study of its results (Bosch et al. 2000, 2006, 2011, 2012; Tarrús 2008). The project was then redesigned and new institutions were incorporated, such as the Autonomous University of Barcelona (UAB), the Archaeological Museum of Catalonia (MAC) and the Spanish National Research Council (CSIC-IMF). During 2008 and 2009 archaeological surveying was carried out on the lake shores—both on land and under water—in order to locate new evidence of settlement and human activity in relation with the prehistoric societies (Bosch et al. 2010; Terradas et al. 2013; Revelles et al. 2014). Finally, from 2010 to the present time, new fieldwork is being conducted in the site (Palomo et al. 2014).

Despite occupying an area of over 8000 m^2 (Bosch et al. 2000), archaeological fieldwork to date has concentrated on an area of *circa* 3000 m^2, 825 m^2 of which have been excavated in the northern part of the settlement where the site is best preserved. From 1991 to 2005, the excavations concentrated on sectors A, B and C (Fig. 8.2). In Sector A, remains of Neolithic settlement are above the water table and hence waterlogged conditions have not been maintained until the present. However, in Sector B the archaeological evidence is covered by the groundwater level and Sector C is fully under water. New excavations from 2010 have focused on Sectors A and D, the latter located to the south of Sector B and with similar preservation conditions.

Two different phases of occupation with distinctive construction traditions have been documented, both situated by pottery styles within the late Cardial Ware Neolithic culture, in the late sixth millennium and early fifth millennium cal BC according to the available radiocarbon dates. Phase I (5320–4980 cal BC) is characterised by the building of wooden structures (presumably dwellings), attested by the hundreds of stakes, poles and planks that have been recovered from the collapse of these constructions. During this phase the village was a pile dwelling site and the preservation of wooden elements has been possible due to anoxic conditions favoured by the silting of the collapsed structures and the rise in the water table since Neolithic times. Besides uncharred timber remains (Bosch et al. 2006; O. López ongoing PhD), the archaeobotanical record consists of other evidence, both charred and uncharred: charcoal (Piqué 2000; Caruso-Fermé and Piqué 2014), seed and fruit remains (Buxó et al. 2000; Antolín and Buxó 2011; Antolín 2013; Antolín et al. 2014; Antolín and Jacomet 2015), plant tissues and fibres (Bosch et al. 2006), pollen (Revelles et al. 2014), etc. All these forms of evidence constitute an extraordinary palaeoecological record for the region, deserving specific strategies for its sampling, recovery and preservation (Antolín et al. 2013; Piqué et al. 2013).

Phase II (5210–4800 cal BC) is represented by large surfaces covered by pavements of travertine slabs on which domestic activities were carried out. This archaeological level had less optimal conditions of preservation and the organic material is mainly found in a charred state, although some hard-coated uncharred material is occasionally found (Bosch et al. 2000, 2011; Antolín 2013; Palomo et al. 2014).

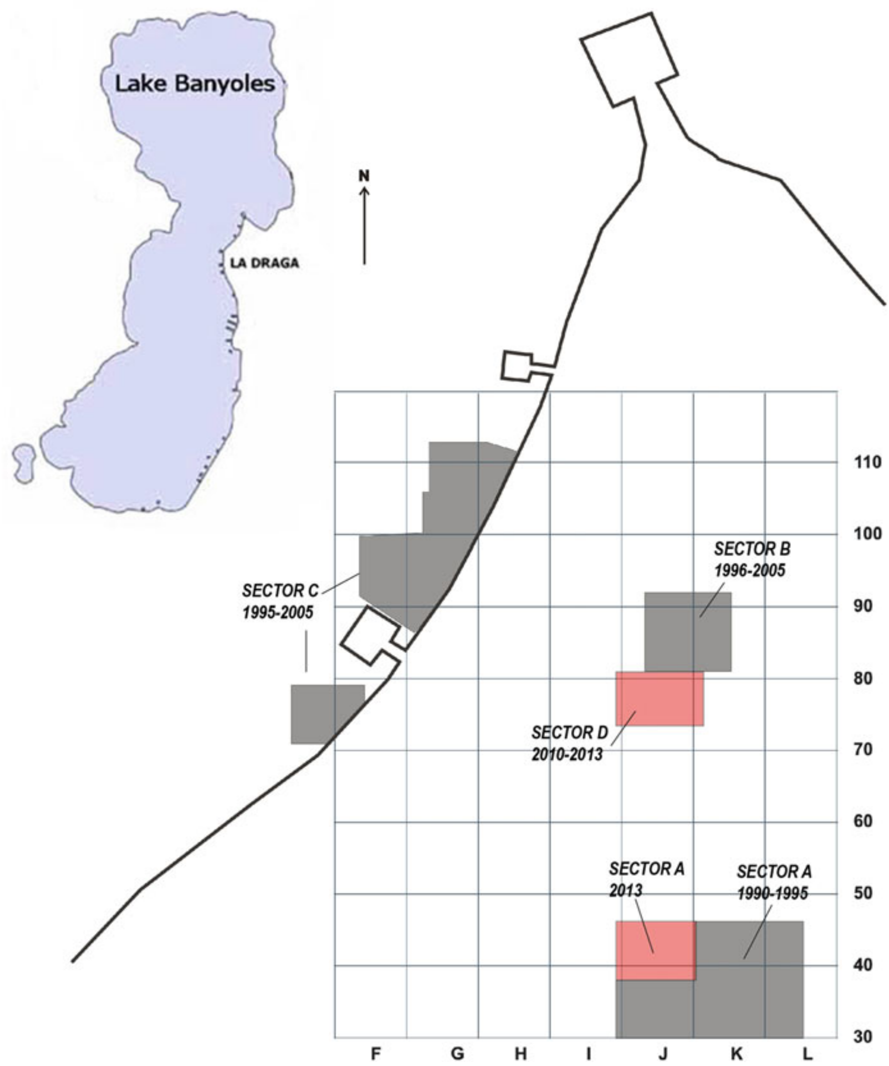

Fig. 8.2 Sectors excavated at La Draga

8.2 Landscape and Wood Resource Exploitation

Palynological data from La Draga show that the area was densely forested with broadleaf deciduous trees (*Quercus, Corylus avellana*), conifers (*Abies alba*, *Pinus* sp.) and riparian trees (*Salix*, *Fraxinus*, *Ulmus*). Several pollen analyses in the surroundings of Lake Banyoles and the archaeological site show an abrupt decline in oak forest cover coinciding with the Early Neolithic settlement of La Draga (Pérez-Obiol 1994; Burjachs 2000; Revelles et al. 2014).

Charcoal analyses carried out at the archaeological site allowed identifying 18 tree and shrub taxa (Caruso-Fermé and Piqué 2014). Taxa from deciduous forests were the best represented in both occupation phases. *Quercus* sp. deciduous was the most important taxa. Shrubs were only represented in very small percentages, although their importance increases in the most recent phase, with the dominant taxa being boxwood (*Buxus sempervirens*) and Rosaceae/Maloideae. Other taxa represented were *Acer* sp. and conifers including yew (*Taxus baccata*), pine (*Pinus sylvestris-nigra*) and juniper (*Juniperus* sp.). The best represented species from the riparian vegetation was laurel (*Laurus nobilis*). Other riparian taxa represented were elm (*Ulmus* sp.), ash (*Fraxinus* sp.), hazel (*Corylus avellana*), willow (*Salix* sp.), alder (*Alnus glutinosa*), elder tree (*Sambucus* sp.), poplar (*Populus* sp.), old man's beard (*Clematis vitalba*) and dogwood (*Cornus sanguinea*). Some of these species might also have grown in the deciduous forest. Finally, some evidence of Mediterranean vegetation was found: holm oak (*Quercus ilex–coccifera*) and strawberry tree (*Arbutus unedo*) were identified albeit in smaller proportions.

The study of timber also shows the importance of the exploitation of deciduous forest by the inhabitants of La Draga. *Quercus* is the dominant taxon in the record (around 95% of remains), and was mainly used to make posts and boards for architectural purposes (Caruso-Fermé and Piqué 2014). Deciduous *Quercus* sp. and *Buxus sempervirens* are the most frequently used raw materials in the manufacture of wooden tools recovered in Phase I (Bosch et al. 2006; Palomo et al. 2013), both being used to make a variety of tools. Other taxa collected in the deciduous oak forests were used more sporadically to make certain artefacts, such as maple (*Acer* sp.), Rosaceae/Maloideae and lime (*Tilia* sp.). Riparian forests were also exploited to obtain wood including dogwood *Cornus* sp., *Corylus avellana*, *Laurus nobilis*, *Populus* sp., *Salix* sp. and *Sambucus* sp. Three types of conifers, *Taxus baccata*, *Pinus* sp. and *Juniperus* sp., and some typically Mediterranean taxa, *Arbutus unedo* and *Quercus* sp. sclerophyllous, were also used to manufacture wooden tools.

8.3 Neolithic Wooden Artefacts from La Draga

The waterlogged context of Phase I implies excellent preservation of the bioarchaeological record, resulting in one of the richest Early Neolithic assemblages. So far there are over 5,000 wooden remains recovered at La Draga, 2,085 of which show signs of having been transformed by human activity. The largest part of this assemblage correspond to posts attributed to the foundations of dwellings, as well as other posts, poles and planks related with the collapse of walls, roofs or other architectural elements. In addition, 177 wooden utensils and tools of many different kinds have been recovered (Fig. 8.3). According to the functional hypotheses arising from ethnographic analogies and archaeological analyses, they can be

Fig. 8.3 Objects and tools made from organic materials: (*1*) rope; (*2*) spoon; (*3*) shovel; (*4*) wooden comb; (*5*) adze handle; (*6*) digging stick; (*7*) hook

related to the following uses (Bosch et al. 2006; Palomo et al. 2011a, 2013; Piqué et al. 2015; de Diego et al. in press):

- Agricultural instruments: represented by 8 harvesting tools and 45 pointed sticks. According to ethnographic and archaeological parallels, as well as the results of our experimental program, we can argue that most of the former were sickle hafts and most of the latter were digging sticks.
- Hunting tools: represented by three bows (two fragmented and one whole), some fragments of possible arrow shafts and projectile points.
- Food processing: a mixer, ladles and containers of various shapes and sizes have been recovered in the category related to food processing.
- Woodworking: represented by ten adze handles, very similar in shape. Together with them are some pieces of wood which have been interpreted as possible wedges.
- Textile production: the three combs recovered and some spindle-like needles may have been used for weaving and spinning within textile production, although other functions cannot be excluded.
- Indeterminate: for many wooden objects it is not possible to suggest a functional hypothesis due to the absence of archaeological or ethnographic parallels, or because they could be multifunctional. Among these are a paddle, some hook-shaped objects, long pointed sticks, etc.

The use of woody raw materials shows a good understanding of their properties by the inhabitants of La Draga (Bosch et al. 2006; Palomo et al. 2013), demonstrating a clear preference for hardwoods like oak and boxwood. The former were used primarily as a building material, almost all posts and poles belong to this taxon, but it was also used to make containers, adze handles and shovels. Boxwood was preferred for making sickle hafts and digging sticks, but also was used to make wedges, needles and combs, among other objects. Some types of objects were made exclusively with one type of wood, such as bows which are all made of yew, shafts of willow, combs of boxwood, containers and shovels of oak.

In accordance with the topic of this chapter we only focus here on the tools used in agricultural activities (digging sticks and harvesting tools). However, a full description of tools and utensils made with organic materials can be found in a monographic publication (Bosch et al. 2006).

8.4 Pointed Sticks Used as Digging Sticks

Pointed and double-pointed sticks are the most abundant wooden tools in La Draga, where 45 items have been recovered so far (Palomo et al. 2013). These instruments are made entirely of wood, so in normal conditions they would be completely invisible in the archaeological record.

Archaeological wooden objects present difficulties when studied with the usual techniques of use-wear analysis. The archaeological artefacts from waterlogged deposits are usually saturated in water when recovered, so the reflection of light on shiny surfaces does not permit a reliable reading and interpretation of the traces. Moreover, once restored, the surfaces tend to be deformed, and some use and technological traces may be altered. In order to solve this circumstance, a structured-light 3D scanner has been used to measure the three-dimensional shape by means of projected light patterns. The equipment used (CSIC-IMF, Barcelona) allows very high precision resolution (0.015 mm) in a great variety of scientific metrology applications. Likewise, the 3D models allow good reproduction and modelling of both the archaeological and the experimental objects, thus enabling the study of use-wear as well as providing a tool with which to register the original modifications due to prehistoric manufacture and use before their deformation by restoration in archaeological laboratories (Fig. 8.4) (Palomo et al. 2013; Piqué et al. 2013). Despite the fragility of archaeological wooden artefacts, their systematic study by means of a 3D scan before restoration allows their surfaces to be recorded with greater precision. This line of research will surely open new ways to approach the understanding of prehistoric tools as well as new pedagogical possibilities in the dissemination of results obtained by archaeological research.

The pointed sticks recovered in La Draga are made in a wide variety of sizes and raw materials, and their length usually fluctuates between 70 and 80 cm, although the longest can reach 130 cm (Bosch et al. 2006). According to this variability, they would probably have had different functions. In some cases these are branches that have been shaped into a sharp end by means of an adze, as can be recognized from

Fig. 8.4 3D models generated from the ends of experimental digging sticks, where deformation of the edge by squashing can be seen

the traces that this stone tool has left over the wood surface. However, the uniformity and standardisation of the double-pointed sticks are noteworthy. These are all made from boxwood (*Buxus sempervirens*) with both ends generally finishing in a point, when they are made from an entire branch, or a pointed end and a bevelled edge with convex delineation at the opposite end, when a longitudinal segment of a boxwood branch is used (Fig. 8.5).

Double-pointed sticks made from a stem segment display facets, removals and various types of traces, some related to processes involved in their production (tool marks such as splitting, adze removals, scratches and sanding marks) and others generated as a result of their use (use-wear like fractures, flattened areas, use-polishes, abrasion and scratches) (Fig. 8.6). Experimental studies have shown that it is possible to discriminate one type of trace from the other, which has allowed

Fig. 8.5 Neolithic digging sticks with a pointed end and a bevelled edge with convex delineation at the opposite end (scale is in centimetres)

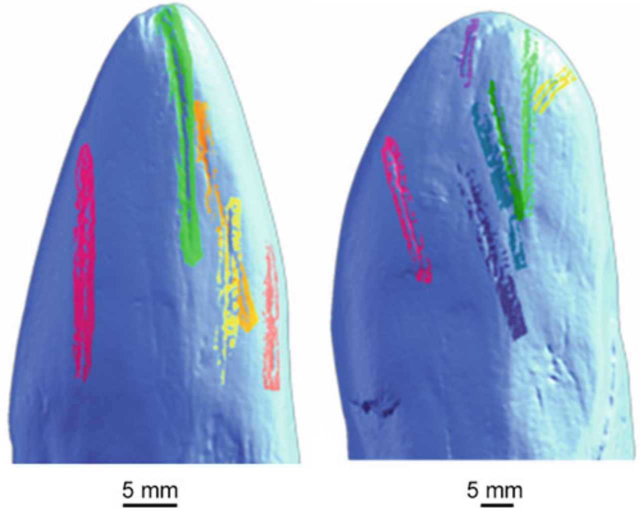

Fig. 8.6 Longitudinal striations generated on the pointed ends of digging sticks

Fig. 8.7 Experimental use of digging sticks turning over the soil surface

confirmation of their use as digging sticks (López et al. 2012). The facets associated with production processes are of different types. Facets produced using wooden wedges to split the stem are long and may have the same length as the stick, while the removals resulting from adze work are short and narrow. Both are visible on the archaeological digging sticks, which also have polished ends.

To determine the function of these instruments has been another of the objective of the study. At first glance, based on ethnographic parallels, it was thought that they were digging sticks, related with the agricultural task of turning the soil over before sowing. Based on this hypothesis, the sticks produced experimentally were used for this task. This not only aimed to ascertain the efficiency of the tools in this specific activity, but also to obtain a complete record of the use-wear resulting from this action on the active parts of the tool. The main activity was driving the end of the stick into the soil and levering it up (Fig. 8.7). The experimental use of digging sticks to turn the soil produced several macroscopic traces: striations, microscars, notches, fragmentation and flattening of the fibres and polishing. It proved possible to characterise them and differentiate them from one another (López et al. 2012). These types of use-wear were also observed in the surfaces and edges of most of the archaeological sticks. In this way, at least 24 items of the 45 pointed sticks are thought to have been used as digging sticks. According to the length of the sticks and the absence of criteria suggesting that these tools were hafted, they would have been used with both hands, in a kneeling position. Their efficacy is restricted to turning the top centimetres of the soil surface, as they do not allow deep rotation of the land.

8.5 Wooden Tools Used in Harvesting Tasks

These tools have already been the subject of a specific publication (Palomo et al. 2011a), and therefore only their more relevant aspects will be mentioned here. More specific details on the tools themselves can also be found in the monograph on the wooden tools from La Draga (Bosch et al. 2006). The harvesting tools found in the

Fig. 8.8 Tool elaborated with a wooden blade, probably used to reap reeds

oldest occupation in La Draga (Phase I) consist of a wooden blade probably used to reap reeds or other aquatic plants and seven sickle handles. Only in one case has a flint blade been found still inserted in the slot in the handle.

The wooden blade is made from deciduous oak (*Quercus* sp.) and consists of a cylindrical haft, finished with a spherical knob at the proximal end and an active part at the opposite end (Fig. 8.8). The active part is a rectangular appendage with a concave cutting edge. This bore several marks that would suggest that it was used to pull up non-woody plant fibre, such as cereals or aquatic plants. At La Draga, not only numerous seeds from different species of domestic and wild plants have been found, but also some basketwork containers made with plant fibres from reeds and other aquatic plants. Thus tools like this one could be used as a reaper, to pull up stems of these plants in order to take advantage of their length for basket making.

The sickle handles were made from juniper wood (*Juniperus* sp.) in one case, elder tree (*Sambucus* sp.) in another and boxwood (*Buxus sempervirens*) in the remaining five. All these types of wood are hard and resilient. The hafts have the same general morphology; they display a rectilinear shaft, where a slot has been made and into which a blade of flint would be inserted mostly in an oblique way. A lateral appendix serves to gather plant stems as part of the harvesting motion (Fig. 8.9). In most cases there is only one slot per shaft, although in one example there are two slots in the same shaft. Despite them not all being whole (only five, plus one fragmented and another shaft fragment with the slot), it is obvious that in all cases the morphology takes advantage of the shape of the branches in the wild, either because the branch was already angle shaped or because it had a secondary branch (Palomo et al. 2013). The dimensions are variable (Table 8.1); the handle made from juniper wood is the largest but it is fragmented and its full length cannot be appreciated.

Fig. 8.9 Sickle handles with lateral appendix. They all have only one slot per shaft apart from number *3* that has two slots. Number *4* is a rough draft of this type of sickle handle

Some traces preserved on the surfaces of the sickle hafts allow a determination of the steps followed in the manufacturing process, even if it is quite variable. Once the blank had been chosen, the shaft and the appendix were generally thinned longitudinally with an adze around their whole perimeter. When the desired length was achieved the shaft was thinned more intensively until it was enough fine to be broken. This type of cutting has been attested for at least two sickle handles as well as for other wooden objects. Furthermore, there are two sickle haft blanks with removals left by an adze-like tool. As regards their finishing, on the one hand, most handles made from boxwood are well polished over their entire surface. On the other hand, the sickle haft made from elder tree wood is the least worked and still preserves the original shape of the branch. In some cases, at the proximal end of the shaft, a knob has been carved so that the sickle could be held more easily.

The form and function of the sickles can be best appreciated in the case of the one made from elder tree wood, which retained its flint blade in place (Fig. 8.10). It consists of a cylindrical haft terminating in a cylindrical knob at the proximal end, with a branch forming a right angle at the distal end. The flint blade was fixed in a groove on the axis of the shaft, obliquely in relation to the handle. According to the phytolith study carried out (Juan 2000), the flint blade was affixed with pine resin (*Pinus sylvestris*). Use-wear analysis of the blade has confirmed its use as a sickle (Palomo et al. 2011a). Very shiny micro-polish was observed, spreading substantially towards the inner area, characteristic of cereal cutting. In the inner part of the micro-polish area, some deep narrow striations both parallel and diagonal to the

Table 8.1 Dimensions of sickles considering the haft, lateral appendix and distance between the slot and the proximal end (all measurements in mm)

		Haft			Appendix				
Reference	Taxon	Length	Width	Thickness	Length	Width	Thickness	Slot distance	Differentiated handle
FG91-1	*Sambucus*	180	22	22.5	83.4	13	13.3	91.6	No
JE83-31	*Juniperus*	140.7	14.6	12	138.4	15	8.4	Unknown	Broken
JI87-13	*Buxus*	194	24	18	116.8	21.5	13	95	93
KB89-6	*Buxus*	210	45	15	59	12	44	60 and 135	No
KA88-12	*Buxus*	204	40	11	Broken	Broken	Broken	125	95
JG90-23	*Buxus*	200	35	20	Broken	Broken	Broken	83	Broken
KD92-5	*Buxus*	200	42	15	92	28	13	100	No

Fig. 8.10 Sickle with lateral appendix where a flint blade was found still inserted in the slot in the handle

edge indicate the sickle kinematics in harvesting activities. According to its morphology, motion dynamics and use-wear observed on the flint blade, the sickle would have been used for cutting the higher part of the stem—ear included—rather than the whole stalk. Indeed, the lateral appendix used to gather plant stems during the harvesting motion would impede a cut close to soil level in order to obtain the ear and most of the stalk (Fig. 8.11). Furthermore, the blade displays no evidence of abrasive soil particles, as specified below.

Fig. 8.11 Experimental harvesting with a replica of a sickle with lateral appendix

8.6 Harvesting Activities Through Flint Blades

Use-wear analysis carried out with the stone tools recovered in La Draga has shown that some flint blades were used as sickle blades in harvesting activities (Gibaja 2011). The knapped stone tool assemblage from La Draga consists of *circa* 1000 items. Most of them (93%) have been knapped in micro-cryptocrystalline flint coming from formations of Oligocene-Miocene age in the Narbonne-Sigean Basin, 110 km north of Banyoles (Terradas et al. 2012). Despite some evidence attesting the development of flint knapping processes in La Draga, the remains characteristic of core shaping-out are found in very small proportions. Therefore, flint products would have been introduced in La Draga largely as cores already shaped out or as blade products already knapped. The most common implemented knapping technique would be indirect percussion, allowing the production of blades that rarely exceed 5–6 cm in length (Palomo et al. 2011b).

A large number of used tools (about 24.6%) were used on non-woody vegetable matter such as cereals. Most of these products are blades of which a large proportion (60%) was used on both their edges, so the cutting edges of the blades would be interchangeable whenever they became unusable. The rest of the tools are flakes, with only one edge used. The characteristics of use-wear on several of these blades, particularly the micro-polishes, are probably connected with cereal reaping. In some cases, due to the presence of specific micro-polishes, it can be proposed that the sickles were used for cutting unripe cereals for limited time periods or even for cutting other kinds of wild plants such as reeds (Gibaja 2011).

Some blades present very extensive micro-polish with many striations produced by a totally rounded edge. Their comparison with similar results obtained from experimentation has revealed that these kinds of use-wear might have developed as a consequence of continuous contact with the ground, during low reaping, cutting the stalk in its lower part or due to the cutting of the culms on the ground (Clemente and Gibaja 1998). According to the distribution of micro-polishes along the flint blade edge, if these blades were hafted they would be parallel to the axis of the sickle handle. Although this type of sickle is well represented by means of the flint blades, as yet in La Draga no wooden haft that could be attributed to this type of sickle has been recovered.

Therefore two types of sickles are attested in La Draga. On the one hand, sickles with a lateral appendix and a single flint blade are inserted obliquely to the shaft. On the other hand, sickles with one or several flint blades are inserted parallel to the shaft. This difference could be related to diverse technical traditions noted in sickle handling in the Western Mediterranean (Ibáñez et al. 2008; Ibáñez et al. 2017). These authors differentiate between straight or curved sickles with short blades inserted diagonally in order to shape a toothed edge (South Portugal, Andalusia and the Spanish Levantine coast), sickles with one or more blades inserted parallel to the handle (Provence and Languedoc, Catalonia, as attested in La Draga by means of the use-wear analysis of flint blades) and places where harvesting activities were carried out without sickles (Cantabrian Spain). These technical traditions seem to be already present in the earliest Neolithic communities settled in these areas, and stay unchanged for over a millennium.

A specific type of sickle with a single blade inserted obliquely to the shaft is well documented in La Draga by the examples of wooden handles (Figs. 8.9 and 8.10). This type of sickle would also be present at other Early Neolithic sites in inland Iberia such as Revilla del Campo and La Lámpara (Ambrona, Soria) (Gibaja 2008), and the mining complex of Casa Montero (Terradas et al. 2011).

8.7 The Archaeobotanical Data: Crops

The carpological record—seed and fruit remains—recovered in the two occupation phases documented at La Draga is very abundant. This chapter focuses on the results obtained for Phase I that provided the wooden tools, and specifically on Sector D, where this phase was clearly identified and proper sampling and sieving techniques were applied (Antolín 2013; Antolín et al. 2013). Samples from three profile columns (*circa* 5 L of volume of sediment), around 40 surface samples (*circa* 30 L of sediment) and several bulk samples were studied in the context of a PhD (Antolín 2013). A previous publication focuses specifically on the charred record from this occupation phase (Antolín et al. 2014).

Several potential crops were identified in both charred and waterlogged states in Phase I (Fig. 8.12): hulled barley (mostly) of two-rowed type (*Hordeum distichum*); naked wheat, mainly of tetraploid type but also of hexaploid type (*Triticum durum/ turgidum*; *Triticum aestivum*); emmer (*Triticum dicoccum*); einkorn (*Triticum monococcum*); the so-called new glume wheat (*Triticum* sp./new type); and

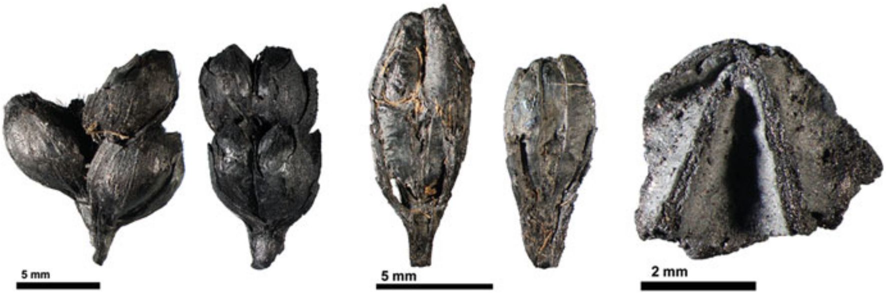

Fig. 8.12 Some of the identified charred crop remains. From *left* to *right*: *Triticum durum*/*turgidum* type, ear fragment; *Hordeum distichum*, ear fragment; and *Papaver somniferum*, capsule fragment (Photo: F. Antolín)

opium poppy (*Papaver somniferum*). The representation of each crop differs depending on the preservation type.

Both grains and chaff remains of barley were significantly better represented in the charred record. In fact, several ear fragments of two-rowed barley were found in charred state in an area where large concentrations of charred grain and chaff were found (probably an *in situ*-burnt store), which was interpreted as a clear sign that they were stored in ear form. Nevertheless, in comparison with naked wheat, it seems to be a secondary crop. Uncharred chaff remains of barley were found but only in small numbers. This probably confirms the lesser importance of the taxon at the site.

Naked wheat is the best represented cereal at La Draga, both in the charred and in the waterlogged record. It was present in almost 90% of the samples from Phase I and high concentrations of remains were found in particular areas, showing that stores could have been burnt *in situ*. It is also the best represented crop in other areas and phases within the settlement (Buxó et al. 2000; Antolín and Buxó 2011). Charred chaff remains of naked wheat were also abundant. Grain was probably stored after manual threshing and almost clean of any weeds (Antolín et al. 2014). The representation of charred remains of glume wheat was rather limited, but einkorn was almost as well represented as naked wheat in the waterlogged record. It is therefore difficult to say if they were minor crops or unwanted contaminants in the fields. No concentrations of any of them were found.

Opium poppy is well attested among the waterlogged remains, being represented in all of the systematic surface samples. Charred remains were very scarce in both levels. The find of a charred capsule fragment could respond to the processing of capsules in the house in order to obtain the grains. The capsule fragments would then be discarded and by chance they might become charred. This is a very rare case, even for a lakeshore site where the preservation of charred remains is better than in dry sites. The different ways in which poppy could have been used at La Draga are, at the moment, unknown. Some of the closest references were found in the La Marmotta site, another Early Neolithic lakeshore settlement near Rome, where the appearance of opium poppy was reported (Rottoli 1993). Apparently, some of these remains could have appeared within a particular ritual context (Merlin 2003). The contexts in which it has appeared so far in La Draga are of domestic type, and they would rather suggest a more regular consumption of the plant. On the other hand, there are no reasons to exclude the possibility that the psychoactive properties of the plant were known and used. No cultivated legumes have as yet been identified in this phase of occupation at La Draga.

Potential weeds are most easily identified in the charred record, due to the more complex routes of entry that affect the waterlogged record. They appeared in low numbers and were mostly annuals (*Avena* sp., *Bromus* sp., *Lathyrus aphaca* type, *Vicia sepium, V. villosa* type). Most of them were classified as 'big-free-heavy', according to the classification of G. Jones (1984), which is typical for cleaned crops. Particularly noteworthy was the relatively large number of legumes within this group of plants. These may be classified as climbing taxa, that is to say, plants which climb on other plants and so are difficult to detach as weeds. No plants of low height were identified. This type of weeds would be a hint towards a high harvesting technique (for a more detailed discussion on this topic see Antolín et al. 2014). This would be in accordance to the type of sickles found at the site.

8.8 Discussion

The analysis of use-wear preserved on tool surfaces and the experimentation carried out on the hypotheses of tool use, in connection with the archaeobotanical data, enable a discussion on the techniques of cultivation and harvesting. In addition, archaeobotanical and geoarchaeological proxies provide helpful evidence to evaluate the impact of these activities on the landscape.

The assemblage of wooden tools used in agricultural practices is quite restricted, being limited to digging sticks and harvesting tools—essentially sickles. Pointed sticks used as digging sticks in La Draga could be used for turning over the soil to improve its oxygenation. Use-wear recorded on their edges and surfaces is similar to that produced during the experimental studies, attesting their use in actions where reiterated contact with abrasive particles—such as these located into the soil—would have occurred. Nevertheless the morphology and size of the digging sticks prevent deep penetration when they are manually stuck into the ground. So, their efficiency is limited to the uppermost layers of the soil, preventing a deep rotation. We cannot exclude the possibility that they were anyway used for this purpose, but alternative interpretations are possible when taking into consideration other proxies.

The use-wear evidence on flint blades used for harvesting activities seems to confirm the presence of two types of sickles, each related with respective harvesting motions and technical traditions attested among the earliest farming communities in the Western Mediterranean. On the one hand, sickles with one or several flint blades were hafted parallel to the axis of the shaft and used in a low harvesting technique, that is to say cutting the stalk by its lower part. This type of sickle would not be represented among the wooden hafts from La Draga. On the other hand, sickles with a single flint blade are inserted obliquely in the sickle shaft. This type of sickle is well attested among the wooden handles, in which a lateral appendix has been shaped out in order to gather plant stems during the harvesting motion. In this case, the sickle would be used for cutting the higher part of the stem—ear included—rather than the whole stalk.

Some experimental studies concluded that sickles with lateral appendix would only be necessary when the plants were not densely sown (Pétrequin et al. 2006). Therefore it is possible that cereals were sown in rows by dibbling with digging sticks such as those recovered in La Draga. The type of potential weeds (climbing taxa, lacking low-growing taxa) identified at the site would also indicate a high harvesting technique (Antolín et al. 2014). Furthermore, the finding of clean grain stores almost lacking weeds would suggest very intensively weeded fields, which would support a medium- to low-density sowing technique. In conclusion, the available data seem to support high harvesting of the crop, between the ear and the first culm node. This would agree with the existence of medium- to low-densely sown fields and the use of the sickle types that were found at La Draga. Similar conclusions were achieved in previous work carried out in the Lake Constance region, at the northern foot of the Alps (Schlichtherle 1992).

Cereals are the most important crop in the site. Among them, the importance of naked wheat from a quantitative point of view should be noted. The fact that the identified weed taxa were mostly annuals would indicate that the cultivation of the fields was permanent, while the presence of plants with vegetative reproduction (like *Vicia sepium*) could indicate intensive soil perturbation. The available archaeobotanical record lacks evidence in favour of shifting agriculture (Bogaard 2002; Antolín 2013; Antolín et al. 2014; Revelles et al. 2014).

In that sense, the opening of farming plots, which were probably small and intensively managed, had a relatively minor impact on the landscape (Antolín et al. 2014). This might enter into some contradiction with some of the palynological data available. New archaeobotanical and geoarchaeological proxies obtained from core sampling carried out on the western shore of Lake Banyoles show how deforestation processes affected natural vegetation development in the Early and Late Neolithic, in the context of broadleaf deciduous forest resilience against cooling and drying oscillations (Revelles et al. 2014, 2015). The first agriculture in the area took place in a densely forested landscape, where riparian and deciduous forests covered the surroundings of the settlement, as shown by pollen and charcoal analyses. The effects of later maintenance of the clearances opened in oak forests should also be taken into account, either for the specific activities related to strategies involved in the management of plant resources or by means of the productive processes implied in an intensive farming system. The intensive exploitation of oak forest to obtain raw materials for the construction of dwellings would be mainly responsible for the large impact on vegetation dynamics at the beginning of the Neolithic occupation at La Draga. Probably, the perpetuation of these clearances was the main anthropogenic impact on the environment during the Neolithic (Revelles et al. 2014, 2015).

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Chapter 9
Farming with Animals: Domesticated Animals and Taxonomic Diversity in the Cardial Neolithic of the Western Mediterranean

Sarah B. McClure and Martin H. Welker

9.1 Introduction

Domesticated animals are a key economic element of early farming in the Western Mediterranean and helped create the spatial, ecological, dietary, and economic relationships of early farming communities. Researchers use faunal data from archaeological contexts to reconstruct these relationships and characterize the nature of early farming in the region. One primary goal is to understand domestic animal management practices and their effects on culture and environment.

Management of sheep, goats, and cattle varied between *agropastoralism* to fully pastoral economies in which people's livelihoods were based on the care, movement, and trade of animals. Ethnographic studies illustrate how variation in pastoral practices affects human social organization (e.g., Halstead 1996; Homewood 2008). Scale (i.e., the size and constituents of herds) and space (i.e., the available forage area) largely frame the cultural and environmental effects of livestock management. *Pastoralists* depend economically on their herds with over 50% of their incomes from livestock and associated products (IFAD 2009). These groups tend to specialize in a single species and use an extensive area, although human participation in the mobility strategy can vary between a few individual herders to entire households or villages. As a result the ecological effects of pastoral land use are variable and determined by a combination of scale, space, and intensity of human involvement (e.g., Halstead 1996; McClure 2015). In contrast, *agropastoralism* refers to the more common range of mixed plant and animal husbandry and is defined by the mostly sedentary nature of communities (Halstead 1996; Koster 1977). Herds tend to be smaller and consist of several different species, and the bulk of subsistence

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income comes from plant agriculture. The term "agropastoralist" is broad: it refers equally to farmers with few animals that can be easily supported on a farm without investment in mobility or foddering, to those practicing regular transhumance or foddering of larger herds.

Researchers are becoming increasingly interested in the ecological impacts of livestock and their role in the short-term construction and long-term maintenance of agricultural landscapes (see McClure 2015 for overview). The ecological implications of management strategies vary along the axes of scale and space mentioned above, as well as species composition of herds. In order to examine and characterize pastoral activities and model their ecological impacts, archaeologists need to construct and provide access to regional data sets, including faunal, botanical, and palaeo-climatic data from Neolithic sites. In many cases, faunal data are limited to species lists from specific sites. Lyman (2015) explored the history of "laundry lists," or species lists comprised of a taxonomic list of species present, generally accompanied by either Number of Identified Specimens (NISP) or Minimum Number of Individuals (MNI) values. Laundry list reporting has been criticized as an inefficient and unimaginative use of faunal data (Olsen 1971). However, Lyman (2015) argues that laundry lists represent quantitatively valuable records that may be standardized and collated with similar data to form databases capable of answering palaeoecological questions on larger geographic or temporal scales. Such analyses rely heavily on the standardization of data to comparable analytical units (e.g., NISP and MNI) and taxonomic categories. Both NISP and MNI have their strengths: NISP in its simplicity and replicability (Grayson 1984; Grayson and Frey 2004) and MNI in its ability to account for differential fragmentation and resistance to taphonomic processing (Beisaw 2013). Both have been shown to reflect one another in a predictable manner (Grayson 1984).

Regional overviews are not uncommon and address a range of questions regarding the spread of agriculture, role of domesticates, and regional variation (e.g., Manning et al. 2013; Rowley-Conwy et al. 2013; Saña 2013; Vigne 2007; Zeder 2008, 2015). However, these studies rarely provide the complete data set, often due to space limitations of edited volumes and journal articles. As a result, other scholars need to reenter data should they wish to build on this work. In this chapter we discuss faunal data from Cardial Neolithic (ca. 5600–5300 cal BC) sites in the Western Mediterranean, spanning Italy to the Spanish Levant (Fig. 9.1). We rely on the published work of researchers who meticulously analyzed faunal assemblages from excavations since the 1950s, and created an Excel spreadsheet that is available open access and in perpetuity for future researchers on *ScholarSphere*.[1] We believe that researchers' time would be better spent pursuing interesting questions and ideas rather than manually entering published data into a database or yet another Excel

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[1] ScholarSphere (https://scholarsphere.psu.edu/) is a digital repository service at The Pennsylvania State University that enables dissemination and long-term preservation and curation of data. The data set used in this analysis is openly accessible in perpetuity under the title "Cardial Neolithic fauna data from the Western Mediterranean."

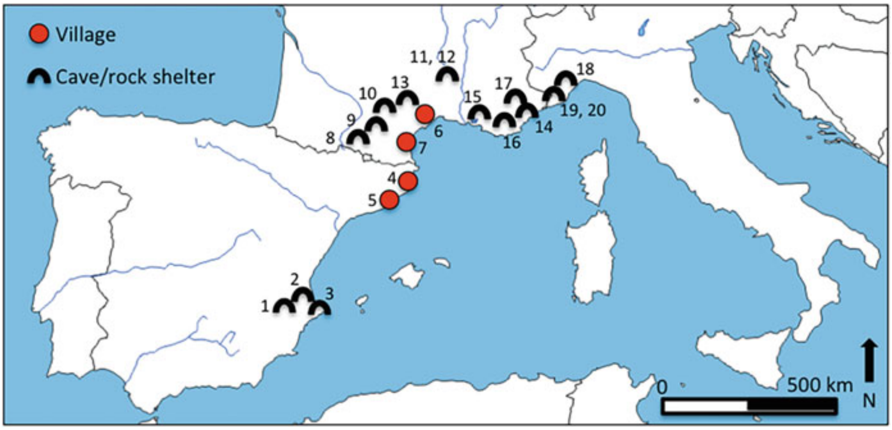

Fig. 9.1 Approximate locations of sites mentioned in the text: (*1*) Abric de la Falguera; (*2*) Cova de l'Or; (*3*) Cova de les Cendres; (*4*) La Draga; (*5*) L'Assentament de la Caserna de Sant Pau; (*6*) Pont de Roque-Haute; (*7*) Leucate-Corrège; (*8*) Dourgne; (*9*) Abri Jean-Cros; (*10*) Grotte Gazel; (*11*) Grotte de l'Aigle; (*12*) Combe Obscure; (*13*) Camprafaud; (*14*) Abri Pendimoun; (*15*) Chateauneuf-les-Martigues; (*16*) Baume Saint-Michel; (*17*) Grotte Lombard; (*18*) Arene Candide; (*19*) Grotta Pertusello; (*20*) Arma dello Stefanin

spreadsheet. The basic, published data analyzed for this chapter is thus readily available to others online, and we encourage our colleagues to similarly provide access to basic data in the future.

In the case of Cardial Neolithic assemblages, we analyze these faunal data to assess the degree that they are comparable with each other, and what they can tell us about human behavior and ecological variation. Data presentation in primary publications varies tremendously, from basic species lists to detailed analyses of age estimations, element representations, cultural modifications, and taphonomic processes. There is little standardization in the reporting of mammalian fauna, let alone for birds, fish, reptiles, amphibians, or mollusks. If the latter are available, they are often published by other specialists and not presented as part of the overall vertebrate assemblages at the site. For this chapter, we included these data where available and our analysis focuses on NISP because it is more frequently reported.

Relative percentages of domesticated species help characterize the economic importance of livestock for early farmers in the region and provide insight into land use and cuisine. However, relatively little attention is paid to the variation in faunal assemblages and its potential to help characterize local environments. To address these issues, we compare published data sets to assess the degree of comparability between assemblages using rarefaction analysis (see Lev-Tov et al. 2011) as well as other measures of assemblage size and species diversity. This approach allows us to compare sites regionally, address differences in animal use between open-air farming villages and caves or rockshelters, and identify commonalities of Neolithic human-animal interactions that have been dwarfed by the predominance of sheep and goat bones. We also highlight smaller taxa that are potentially more informative of local environmental or climatic conditions, regardless of if their presence in the assemblage is the result of cultural or natural processes. We begin the chapter with a general background on current understandings of Neolithic livestock management and then turn specifically to the Western Mediterranean assemblages to assess species diversity and differences in settlement types, and discuss the utility of accessible regional datasets.

9.2 Neolithic Animal Management

The spread of farming into Europe occurred along multiple behavioral pathways. Archaeologists look to the Balkans to characterize the spread of farming in Europe because chronologies and the material record point to this region as a departure point for Near Eastern farming traditions throughout Europe. Ceramic styles in particular link some areas with the spread of farming into central Europe, while Impressed Wares in the Adriatic show connections throughout the Central and Western Mediterranean (Ammerman and Biagi 2003; Price 2000).

Various combinations of migrating farming populations and acculturation of indigenous hunter-gatherers helped farming spread into interior locations and along the coast of southeastern Europe (Bailey 2000; Forenbaher and Miracle 2006; Greenfield 2008; Legge and Moore 2011; Miracle and Forenbaher 2006; Özdoğan 2011; Tringham and Krstić 1990; Tringham 2000). In some parts of the Balkans farming appears suddenly with a full dependence on plant and animal husbandry. This is visible archaeologically in the faunal and botanical data from substantial village sites occupied for centuries or millennia (e.g., Bailey 2000; Legge and Moore 2011; Marijanović 2009; McClure et al. 2014; Moore et al. 2007; Perlès 2001). Other areas have evidence for a greater range of subsistence practices and degrees of sedentism, such as the Iron Gates region with its diverse record of farming and pastoral communities and interactions with indigenous hunter-gatherer groups (Bailey 2000; Bonsall et al. 2008; Borić and Price 2013; Greenfield and Jongsma 2008; Tringham 2000).

Given the spatial and temporal position of early farming societies in the Balkans, animal management practices found in this region should provide a blueprint for the subsequent spread of animal husbandry. However, evidence for domestic animal management is varied (e.g., Arnold and Greenfield 2006; McClure 2013; Orton 2012). Despite the ubiquity of domesticated animals in faunal assemblages throughout the region (see overviews in McClure 2013; Orton 2012), Greece and the Balkans exhibit no clear evidence for large-scale mobile pastoralism until the Bronze Age (e.g., Halstead 1996; Arnold and Greenfield 2006), although Greenfield and Jongsma (2008) present evidence of sedentary pastoralists in Neolithic Romania. The diversity of data for the Balkans and long-standing debates on the degree of mobility and pastoralism in the region led Halstead (1996) to define distinctive zooarchaeological signatures based on historic data for pastoralism (e.g., herd size and composition; degree of mobility and animal nutrition; labor requirements; production for exchange) to distinguish between large-scale pastoralism and small-scale mixed farming households. Based on his analyses of the prehistoric archaeological record, he argues that Greek Neolithic animal management was part of a small-scale household farming economy, but also considers the possibility of small-scale or "self-sufficient" pastoralism (Halstead 1996:33). The eastern Adriatic archaeological data suggests that pastoralists were common in areas of higher elevation or rockier terrain during the Neolithic (e.g., Istria, Slovenia; see Bonsall et al. 2013; Miracle 2006; Mlekuž 2006; Mlekuž et al. 2008). Research on coastal Neolithic village settlements in northern Dalmatia indicates a dominance of domesticates in the faunal assemblages (Legge and Moore 2011; McClure et al. 2014; McClure and Podrug 2015), but research on the antiquity of transhumance remains inconclusive (Forenbaher 2011; Zavodny et al. 2014).

In contrast to the variable nature of migration and acculturation in the Balkans, Neolithic farming enclaves in the Western Mediterranean appear almost simultaneously in southern France and eastern Spain, suggesting a coastal migration of farming populations, followed by rapid spread of farming through colonization and acculturation of local hunter-gatherers in what has been termed a "cultural duality model" (Bernabeu Auban 1996; Juan-Cabanilles and Martí Oliver 2002; Juan-Cabanilles and García Puchol 2013; Rowley-Conwy et al. 2013; Zilhão 2001; Zeder 2015). The archaeological record for this period is different than elsewhere in Europe. Only few Neolithic villages have been identified and excavated in the Languedoc and Provence of southern France, or the eastern coast of the Iberian Peninsula. This is likely due to truncations of sites or burial under colluvium due to geomorphological shifts and major erosion in the Early and Middle Holocene (Berger 2005; Berger and Guilaine 2009). As a result, much of our knowledge regarding early farming societies in this area, and in particular their domestic animal management strategies, comes from cave and rockshelter sites.

Although the biased settlement record has a number of limitations for reconstructing Neolithic livelihoods, the excellent preservation of faunal remains in cave and rockshelters provides ample evidence of pastoral activity. Neolithic seasonal mobility has been clearly documented at many sites in the Western Mediterranean through faunal remains, evidence of penning, geomorphology, and coprolites (e.g., Angelucci et al. 2009; Badal 1999; Boschian and Montagnari-Kokelj 2000; Bréhard et al. 2010; Molina et al. 2006; Rowley-Conwy et al. 2013): for example, sheep dominate faunal remains at sites such as Abri Pendimoun, a rockshelter in the Provence spanning the early Neolithic. Geomorphological studies support the interpretation based on shed caprine teeth that animals were seasonally penned inside the shelter (Binder et al. 1993; Binder and Sénépart 2010; see also discussion in Rowley-Conwy et al. 2013). Similar patterns are visible at other sites in the region including Fontbrégoua and Grotte Lombard, both interpreted as seasonal encampments by herders with likely connections to (unidentified) permanent village settlements (Binder and Sénépart 2004; Rowley-Conwy et al. 2013).

In the few villages in the Western Mediterranean with well-preserved faunal remains, a greater diversity in domestic animal species is identified, including sheep, goats, pigs, and cattle. For example, Pont de Roque-Haute is the earliest known Neolithic site in the Languedoc region of southern France, dating to 5700 cal BC (Guilaine et al. 2007), and the faunal assemblage is also dominated by sheep (Vigne and Carrère 2007). Leucate-Corrège similarly has a strong presence of sheep, although cattle are also well represented (Rowley-Conwy et al. 2013; Geddes 1984). This stands in contrast to the data from other parts of the central Mediterranean, where cattle husbandry is more common, including northern Italy and the Croatian region of Istria. Piancada in the Italian Friuli region is an open-air site where the majority of faunal remains are cattle (Rowley-Conwy et al. 2013:165; Petrucci and Riedel 1996; Petrucci et al. 2000); however nearby cave sites at Pupicina (Miracle and Pugsley 2006) and Edera 2a (Boschin and Riedel 2000) are dominated by ovicaprids. Rowley-Conwy et al. suggest that this difference could be due to functional differences between the sites: “they might be pastoral stations occupied seasonally by people from the large open-air Neolithic settlements” (2013:165).

Few open-air sites on the Iberian Peninsula have sufficient bone preservation, but sites such as La Draga provide some insight into domestic animal management. Dated to ca. 5300 cal BC, the site has over 50 species of wild and domestic vertebrate faunal remains represented, dominated by the domestic assemblage (Saña 2013). In contrast to elsewhere, the domesticates are more evenly represented by ovicaprids (ca. 40%), cattle (ca. 32%), and pigs (ca. 21%) (Saña 2013; Saña et al. 2014). Although there has been little discussion of the relationship between villages and caves or rockshelters, similar patterns are discernable to elsewhere in the Western Mediterranean. Ovicaprids dominate cave and rockshelter assemblages on the Iberian Peninsula (although some have significant proportions of wild species represented; Saña 2013) and in some cases other evidence for seasonal use and ovicaprid penning is documented (e.g., Badal 1999; Molina et al. 2006).

Archaeological study of Neolithic human-animal interaction has emphasized the importance of livestock, particularly the apparent predominance of sheep and goats in the Mediterranean region. In this chapter, we take a different approach to more equally assess both wild and domestic animals in early farming sites. In particular, we advocate for regional datasets to be generated and compared. The challenge in the Western Mediterranean is twofold. First, we should expect differences in the presence, use, seasonality, and species composition between villages and rockshelters/caves since they represent complementary but different activity areas for early farmers. Secondly, we need to address the degree of comparability between available data sets from these sites, incorporating issues of sample size, species diversity, and reporting practices.

Lev-Tov et al. (2011) outline a procedure for undertaking such a regional investigation. Their analysis of Early Iron Age animal economies compared faunal evidence from Khirbat al-Mudayna al-‘Aliya in west-central Jordan to other early Iron Age sites in the southern Levant. Despite the heavy predominance of sheep and goat pastoralism at all sites analyzed and a traditional emphasis on ethnicity and identity as explanatory mechanisms for husbandry practices, the authors compared assemblages and identified important issues relating to the diversity of animal economies in this period (2011:86). First, they found that a community's animal economy cannot be predicted based solely on its environmental zone but rather "was a consequence of local contingencies" including nearby markets, subsistence demands, and local traditions. Second, people were able to create a sustainable animal economy regardless of environmental location, demonstrating flexibilty in animal management practices adapted to local environments. As Lev-Tov et al. (2011:86) state, "proximate settlements could organize their animal economies in very different ways," and the factors determining that organization were not solely dependent on ethnic differences between sites.

This approach allows us to characterize the faunal assemblages regionally by comparing sample sizes, species diversity, and locations. In the following we present the faunal data used in this study and specific issues regarding the nature of the assemblages, sites, and reporting styles. We then turn to discussing sample sizes and species diversity before returning to domestic animal use in the Cardial Neolithic of the Western Mediterranean.

9.3 The Faunal Data: Context, Collection, and Sample Size

This study analyzes published data from 20 Cardial Neolithic sites in the Western Mediterranean (Fig. 9.1 and Table 9.1). We strived to include as many sites as possible with Cardial Neolithic levels; however sample size was limited by the availability and accessibility of published fauna reports (e.g., unpublished dissertations; limited print reports) or incomplete reporting (e.g., publications dealing with only a subset of data). As a result, known sites such as Fontbrégoua or Fraischamp with potentially important contributions to this kind of study were not included in the analysis (Helmer 1979; Rowley-Conwy et al. 2013).

Data from open-air sites are particularly limited. Cardial Neolithic villages like Mas d'Is (Bernabeu Auban et al. 2003, 2014a, b; Diez Castillo et al. 2010) or Benàmer (Torregrosa Giménez et al. 2011) in the Alcoi Basin of eastern Spain provide detailed information on village structure and craft production, but bone survival was minimal and only few faunal remains were recovered. For this study, we include data from four villages: L'assentament de la Caserna Sant Pau (Colominas et al. 2008) and La Draga (sectors B and D; Antolín et al. 2014) in Catalonia, Spain, and Pont du Roque-Haute (Vigne and Carrère 2007) and Leucate-Corrège (Geddes 1980, 1984) in Languedoc, France. Of these, the well-preserved site of La Draga, dated to 5300–5200 cal BC (Antolín et al. 2014: Saña 2000, 2013), is particularly noteworthy. Although not fully contemporary with the earliest Neolithic in the area, extensive anaerobic deposits, excellent bone preservation, and precise collection strategies resulted in the recovery of the largest faunal assemblage from a Neolithic village in the Western Mediterranean (Table 9.1). As such, La Draga provides an interesting counterpoint to the caves and rockshelters that dominate what we know about early Neolithic animal management practices on the Iberian coast. We include La Draga's faunal remains from the

Table 9.1 Summary data used in analysis by site

Site	Level/context	Site type	Region	Total Frag	NISP—id	% ID	Total MNI	References
Abri Jean Cros	nc2a-c	Cave/rockshelter	Languedoc	6301	1973	31	133	Poulain (1979), Guilaine (1979), Geddes (1980)
Baume Saint—Michel		Cave/rockshelter	Languedoc	92	92	100	n/a	Hameau et al. (1994)
Combe Obscure	c6	Cave/rockshelter	Languedoc	268	250	93	n/a	Helmer (1991)
Comprafaud		Cave/rockshelter	Languedoc	n/a	2427	n/a	n/a	Rodriguez et al. (1983)
Dourgne	C6	Cave/rockshelter	Languedoc	n/a	778	n/a	n/a	Geddes (1980)
Grotte Gazel	Gazel 1	Cave/rockshelter	Languedoc	n/a	800	n/a	n/a	Geddes (1980)
La Grotte de l’Aigle		Cave/rockshelter	Languedoc	2914	1162	40	80	Roudil et al. (1979)
Arene Candide	1940–1950; levels 25–28	Cave/rockshelter	Liguria	n/a	1462	n/a	n/a	Rowley-Conwy (1997), Bartolomei (1997)
Arene Candide	1972–1977; strata 14 and 15	Cave/rockshelter	Liguria	15,860	4149	26	934	Sorrentino (1999)
Arene Candide Total		Cave/rockshelter	Liguria	17,321	5611	32	n/a	
Arma dello Stefanin	(Level III; 1988)	Cave/rockshelter	Liguria	3846	749	20	n/a	Barker et al. (1990), Leale Anfossi (1972)
Grotta Pertusello	Level IV	Cave/rockshelter	Liguria	873	811	93	n/a	Barker et al. (1990), Leale Anfossi (1958–1961)
Abri Pendimoun		Cave/rockshelter	Provence	236	214	91	n/a	Binder et al. (1993)
Chateauneuf-les-Martigues		Cave/rockshelter	Provence		788	n/a	n/a	Ducos (1958)
Grotte Lombard		Cave/rockshelter	Provence	1000	839	84	45	Binder et al. (1991)
Abric de la Falguera	Phase VI	Cave/rockshelter	Valencia		732	n/a	n/a	Carrión Marco et al. (2006)
Cova de l’Or	Sect. J4, J5	Cave/rockshelter	Valencia		1221	n/a	477	Pérez Ripoll (1980)
Cova de les Cendres	Nia	Cave/rockshelter	Valencia	3814	2780	73	205	Iborra Eros and Martinez Valle (2009)
L’assentament de la Caserna Sant Pau		Village	Catalonia	2404	1455	61	n/a	Colominas et al. (2008)
La Draga	Sect. B, D	Village	Catalonia	8526	5282	62	197	Antolín et al. (2014)
Leucate-Correge		Village	Languedoc	372	196	42	25	Geddes (1980, 1984)
Pont de Roque-Haute		Village	Languedoc	946	452	31	28	Vigne and Carrère (2007)

Multicomponent sites have specific levels or contexts listed for data used in analysis. Faunal data include total number of fragments (Total Frag), number of identified specimens (NISP-id), percentage of the assemblage that was identified (% ID), and total minimum number of individuals (MNI) where available well-preserved, wet sieved levels of Layer VII in sectors B and D that constitute their earliest occupation.

In addition to the four village sites, this study includes data from 16 cave and rockshelter sites along the Western Mediterranean, spanning Valencia, Languedoc, Provence, and Liguria. Many of these sites contain cultural deposits from multiple time periods. We include the faunal data from only those levels that are clearly described as Cardial Neolithic in date and follow the excavator's or analyst's interpretations of chronology. In some cases, AMS ^{14}C radiocarbon dates are available (e.g., Abric de la Falguera, Arene Candide); in others, Cardial ceramics provide the basis for temporal attribution. In all cases, faunal remains were recovered by screening sediments; however most studies did not provide specific information on mesh sizes or what portion of soils were screened during excavation.

As can be seen in Table 9.1, the total sample size varies between sites as does the proportion of fragments identified to species. Variability in sample size is related to a variety of factors including the original depositional environment, taphonomic processes, extent and number of excavations, and recovery methods employed. The influence of preservation is particularly clear at La Draga (Antolín et al. 2014; Saña et al. 2014). As one of the largest and best preserved assemblages in the Western Mediterranean, the faunal assemblage stands in striking contrast to the poor preservation from other Spanish Mediterranean village sites. Furthermore, Saña et al. (2014) were able to identify significant differences in the degree of bone preservation within La Draga's excavation units depending on variations in anaerobic and aerobic depositional contexts.

A number of the sites used in this chapter were excavated at multiple times and different analysts published the faunal remains independently. For example, Sorrentino (1999), Bartolomei (1997), and Rowley-Conwy (1997) independently published reports on fauna from different sectors of Arene Candide's Neolithic levels or different aspects of the faunal assemblage. Rowley-Conwy (1997) analyzed material from Bernabò Brea's 1950s' excavations that included many small elements and fragments thanks to extensive dry sieving during excavation. Levels 28–25 are attributed to the "Early Neolithic Impressed Ware Culture," dating to 6900–6150 BP (uncalibrated from Maggi 1997). Bartolomei (1997) reports the bird bone identifications along with some (but not all) of the small mammal remains. Though published in the same volume, the relationship between Bartolomei's small mammal study and Rowley-Conwy's small mammal identifications is unclear. Sorrentino's (1999) extensive analysis of the faunal remains from the 1972–1977 excavations at the site includes mammals, birds, amphibians, and even a reptile. However, Sorrentino classified all pigs as *Sus scrofa*, but lists them in the narrative as domesticates, while Rowley-Conwy's analysis only lists *Sus sp*., suggesting a more conservative approach to the identification of domestic or wild pigs. Upon reanalysis, Rowley-Conwy et al. (2013) argue that all the Early Neolithic pigs at Arene Candide were wild and domestic pigs only appeared in the Late Neolithic. In this chapter, we follow this most recent analysis and treat all Arene Candide pigs as wild.

Two publications of faunal remains from Stefanin III highlight additional curatorial issues that influence the nature of archaeological animal bone assemblages. Leale's (1972) study of the faunal assemblage included over 3000 unidentifiable bone fragments. Upon reanalysis, Barker et al. (1990) found that all originally deemed "unidentifiable" bone had been disposed. There were discrepancies in the identifications of individual bones, but the relative proportions of species remained comparable between the two studies (Barker et al. 1990). For our analysis, we added the number of unidentifiable bone fragments from Leale's (1972) study to better represent the assemblage as a whole, but used Barker et al.'s (1990) species identifications.

Despite these differences in taphonomy, recovery, and curation, the data sets presented here provide insights into the interactions between early farmers and wild and domestic animals. In the following, we assess the comparability of assemblages and identify differences in species diversity and abundance among early Neolithic sites in the region.

9.4 Sample Size and Diversity

Sample sizes reflect a combination of context, collection procedures, size of excavation, and site taphonomy. Sample size tends to have a large influence on the recovery of taxonomic diversity, since rare taxa are more likely to be identified in larger faunal assemblages (Grayson 1984; see also Lev-Tov et al. 2011). This is also the case for Cardial Neolithic sites in our sample, although the relationship is dependent on site type. Figure 9.2 presents the number of identified specimens and the number of taxa identified for all sites in this study (see also Table 9.2). Due to differences in reporting, nonmammalian fauna (e.g., birds, fish) were counted as a single taxon when present. In addition, if only ovicaprids or *Sus* sp. were listed, they were counted as two taxa, since they likely contained both sheep and goats or wild and domestic pig, respectively. Although this approach has limitations, these criteria were used consistently on all sites in the study.

Figures 9.2, 9.3, and 9.4 present the bivariate linear analysis of the relationship between sample size (NISP) and number of identified taxa for the sites captured in this study. A significant correlation between sample size and identified taxa is presented in Fig. 9.2a ($r = 0.6881$; $p = 0.00079745$)—in other words, more species are identified as the sample size increases. However, less than half of the variation in number of taxa is explained by sample size ($r^2 = 0.47348$). In contrast, the equation is a much better fit when only cave and rockshelter assemblages are analyzed (Fig. 9.2b). In this case, the correlation is even stronger ($r = 0.89933$; $p = 2.1458\text{E-}06$) and 80% of the variation in number of taxa is explained by sample size alone ($r^2 = 0.80879$). When villages are analyzed independently from other sites (Fig. 9.2c), the correlation is statistically insignificant ($r = 0.93016$; $p = 0.069838$). In other words, there is no significant correlation between sample size and number of taxa in the assemblage.

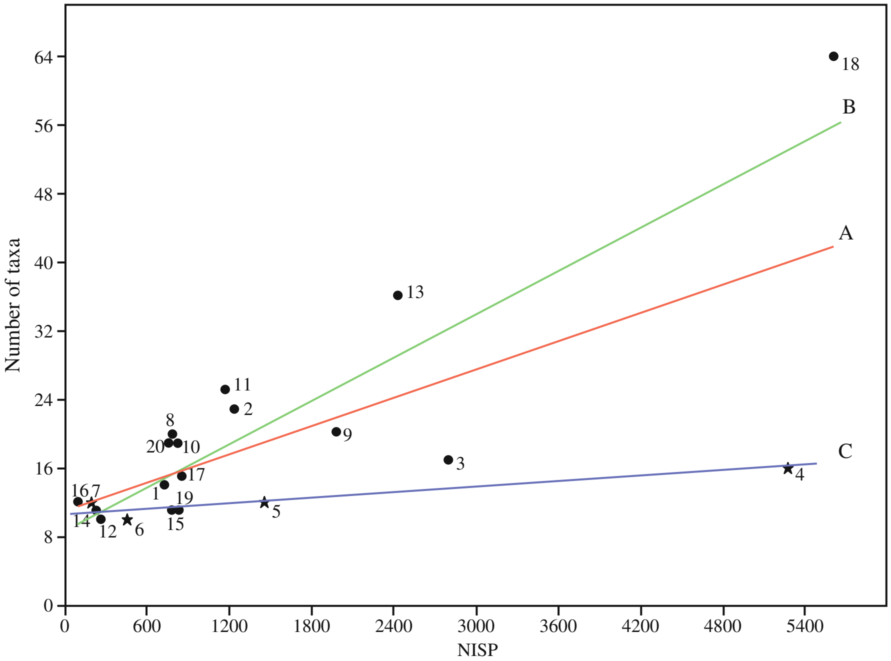

Fig. 9.2 Bivariate linear model of Number of Identified Specimens (NISP) and number of all taxa identified in the assemblage: (**a**) all sites; (**b**) cave and rockshelter sites (*circles*) only; (**c**) village sites (*stars*) only. Sites: (*1*) Abric de la Falguera; (*2*) Cova de l'Or; (*3*) Cova de les Cendres; (*4*) La Draga; (*5*) L'Assentament de la Caserna de Sant Pau; (*6*) Pont de Roque-Haute; (*7*) Leucate-Corrège; (*8*) Dourgne; (*9*) Abri Jean-Cros; (*10*) Grotte Gazel; (*11*) Grotte de l'Aigle; (*12*) Combe Obscure; (*13*) Camprafaud; (*14*) Abri Pendimoun; (*15*) Chateauneuf-les-Martigues; (*16*) Baume Saint-Michel; (*17*) Grotte Lombard; (*18*) Arene Candide; (*19*) Grotta Pertusello; (*20*) Arma dello Stefanin

Given differences in reporting nonmammalian fauna, we conducted the same analysis with only mammalian taxa (Table 9.2). As can be seen in Fig. 9.3a, there is statistically significant correlation between sample size and the number of identified mammalian taxa ($r = 0.70032$, $p = 0.00058517$), although this model only explains 49% of the variation ($r^2 = 0.49045$). When the village sites are taken out of the analysis and only cave and rockshelter assemblages are targeted (Fig. 9.3b), the correlation between sample size and number of identified taxon becomes much stronger ($r = 0.85877$, $p = 2.0517\text{E-}05$) and 73% of the variation in number of mammalian taxa is explained by sample size alone ($r^2 = 0.73748$). However, open-air sites are very similar in the number of identified taxa regardless of sample size with no significant correlation (Fig. 9.3c; $r = 0.89871$; $p = 0.10129$).

Half of the sites ($n = 11$) in this analysis included data on very small mammals (micromammals, e.g., voles, bats, dormice), although the reporting differs in the degree to which species were identified or lumped into general taxonomic categories (Table 9.2). The absolute numbers of micromammals are small. To test if

Table 9.2 Summary of data used in analysis

Site	# Taxa	# Mammal taxa	# Micro-mammal taxa	# Wild mammal taxa	% Ovis/ Capra	% *Bos taurus*	% *Sus domesticus*	% Wild	NISP/% *Canis familiaris*
Abri Jean Cros	20	17	1	13	33.4	11.9	22.4	31.9	7/0.4
Baume Saint—Michel	12	11	0	9	12	4.3	0	83.7	0/0
Combe Obscure	10	10	0	8	48	16.8	0	35.2	0/0
Comprafaud	36	23	4	19	22.5	8.7	16.9	51.7	7/0.2
Dourgne	20	16	1	15	10.2	n/a	n/a	75.2	0/0
Grotte Gazel	19	16	0	14	46.2	n/a	n/a	32.9	5/1
La Grotte de l’Aigle	25	21	1	18	26.3	19.7	35.6	18.4	0/0
Arene Candide	24	18			54	n/a	n/a	46	1/0.07
Arene Candide	60	33			39.2	1.4	18.5	40.9	2/0.005
Arene Candide Total	64	34	9	30	42.9	1	0	56.1	3/0.0005
Arma dello Stefanin	19	16	1	15	10.1	n/a	0	89.9	0/0
Grotta Pertusello	11	10	0	8	43.4	12.9	0	43.7	0/0
Abri Pendimoun	11	11	0	9	78	4.2	n/a	4.2	0/0
Chateauneuf-les-Martigues	11	11	1	10	27.4	n/a	n/a	66.9	0/0
Grotte Lombard	15	15	0	12	9.3	1.8	n/a	78.7	1/0.1
Abric de la Falguera	14	14	0	11	18.9	0.4	n/a	79.8	1/0.1
Cova de l’Or	23	20	3	16	55.3	2	14.5	27.4	10/0.8
Cova de les Cendres	17	15	0	12	28.6	n/a	10.7	59.7	2/0.1
L’assentament de la Caserna Sant Pau	12	12	0	8	50	22.6	13.7	13.1	9/0.6
La Draga	16	16	0	12	42.5	28.9	24.4	3.4	42/0.8
Leucate-Correge	12	11	0	8	51.9	6.4	n/a	21.8	1/0.6
Pont de Roque-Haute	10	8	0	6	86.2	5.5	0	8.3	0/0

Total number of taxa includes all taxa (mammalian and nonmammalian) identified at each site

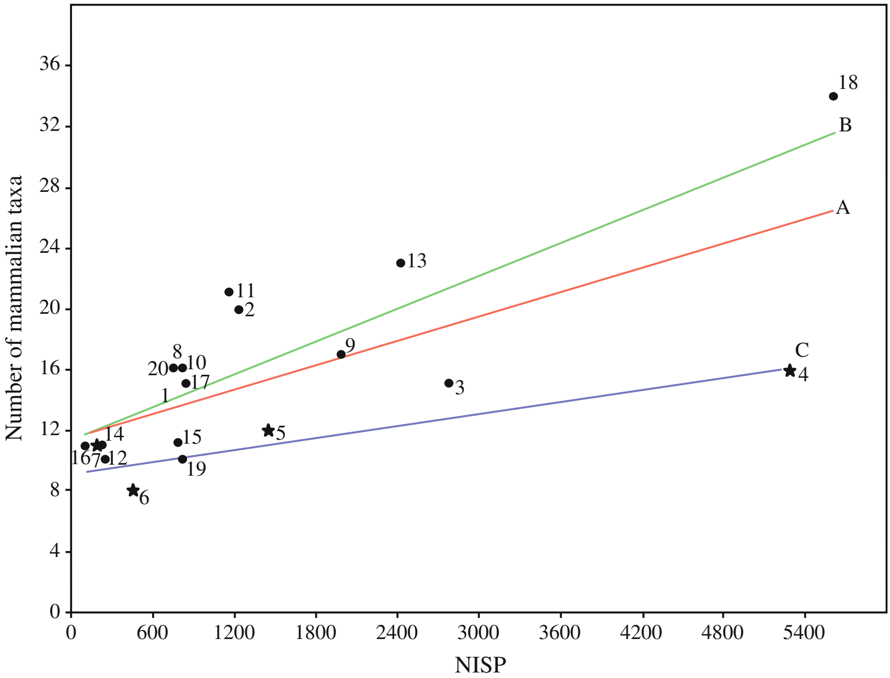

Fig. 9.3 Bivariate linear model of Number of Identified Specimens (NISP) and number of mammalian taxa identified in the assemblage: (**a**) all sites; (**b**) cave and rockshelter sites (*circles*) only; (**c**) village sites (*stars*) only. Sites: (*1*) Abric de la Falguera; (*2*) Cova de l'Or; (*3*) Cova de les Cendres; (*4*) La Draga; (*5*) L'Assentament de la Caserna de Sant Pau; (*6*) Pont de Roque-Haute; (*7*) Leucate-Corrège; (*8*) Dourgne; (*9*) Abri Jean-Cros; (*10*) Grotte Gazel; (*11*) Grotte de l'Aigle; (*12*) Combe Obscure; (*13*) Camprafaud; (*14*) Abri Pendimoun; (*15*) Chateauneuf-les-Martigues; (*16*) Baume Saint-Michel; (*17*) Grotte Lombard; (*18*) Arene Candide; (*19*) Grotta Pertusello; (*20*) Arma dello Stefanin

micromammals skew the analysis in a meaningful way, we omitted them from the data set for Fig. 9.4. When micromammals are taken out of the analysis, the same general pattern is visible: there is statistically significant correlation between sample size and number of identified mammalian (no micromammals) taxa ($r = 0.65176$, $p = 0.0018481$), although this model only explains 42% of the variation ($r^2 = 0.42479$) (Fig. 9.4a). When only cave and rockshelter assemblages are analyzed (Fig. 9.4b), the correlation between sample size and number of identified taxon becomes somewhat stronger ($r = 0.75904$, $p = 0.00065032$), but only 58% of the variation in number of mammalian taxa is explained by sample size alone ($r^2 = 0.57614$). None of the village sites reported micromammals, so they are not included here.

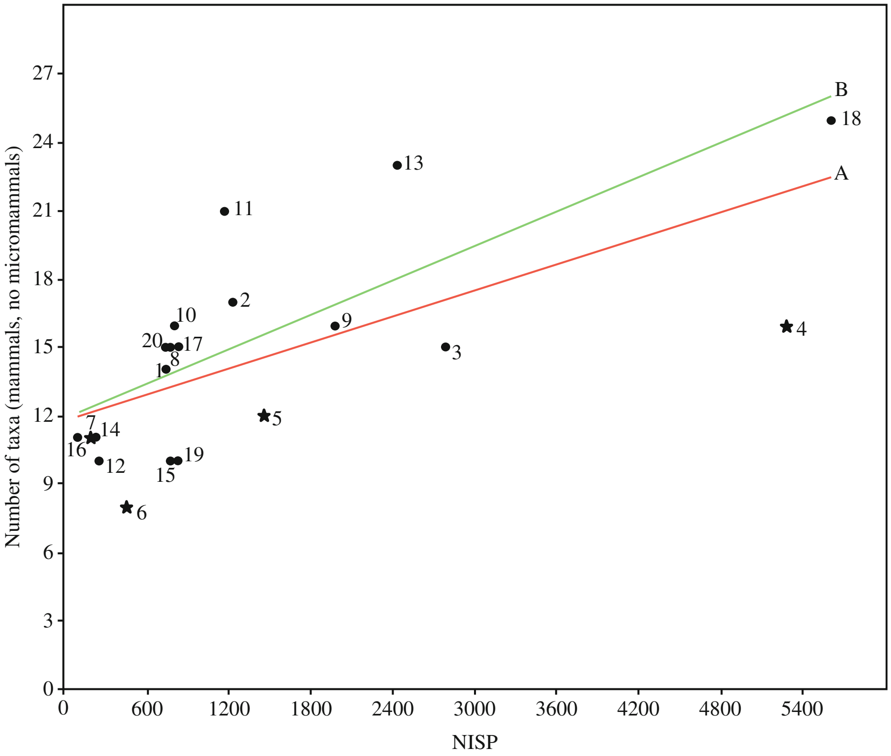

Fig. 9.4 Bivariate linear model of Number of Identified Specimens (NISP) and number of mammalian taxa (no micro-mammals) identified in the assemblage: (**a**) all sites; (**b**) cave and rockshelter sites (*circles*) only. Villages (*stars*) did not report micro-mammals. Sites: (*1*) Abric de la Falguera; (*2*) Cova de l'Or; (*3*) Cova de les Cendres; (*4*) La Draga; (*5*) L'Assentament de la Caserna de Sant Pau; (*6*) Pont de Roque-Haute; (*7*) Leucate-Corrège; (*8*) Dourgne; (*9*) Abri Jean-Cros; (*10*) Grotte Gazel; (*11*) Grotte de l'Aigle; (*12*) Combe Obscure; (*13*) Camprafaud; (*14*) Abri Pendimoun; (*15*) Chateauneuf-les-Martigues; (*16*) Baume Saint-Michel; (*17*) Grotte Lombard; (*18*) Arene Candide; (*19*) Grotta Pertusello; (*20*) Arma dello Stefanin

9.4.1 Diversity and Evenness

Standard zooarchaeological NISP and MNI are measures of the number of species represented and allow us to compute their relative proportions in an assemblage. However, measuring the significance of a particular species in an assemblage often requires understanding how many of each taxa are represented and how a particular species abundance compares to that of others in the assemblage. A variety of indices are used in ecology to incorporate measures of species richness and distribution of taxa within a sample (Lyman 2008). The Shannon-Weaver diversity index in particular provides a measure of species diversity and evenness within an assemblage and is often used in zooarchaeological research (see Lyman 2008; Reitz and Wing 2008; Lev-Tov et al. 2011).

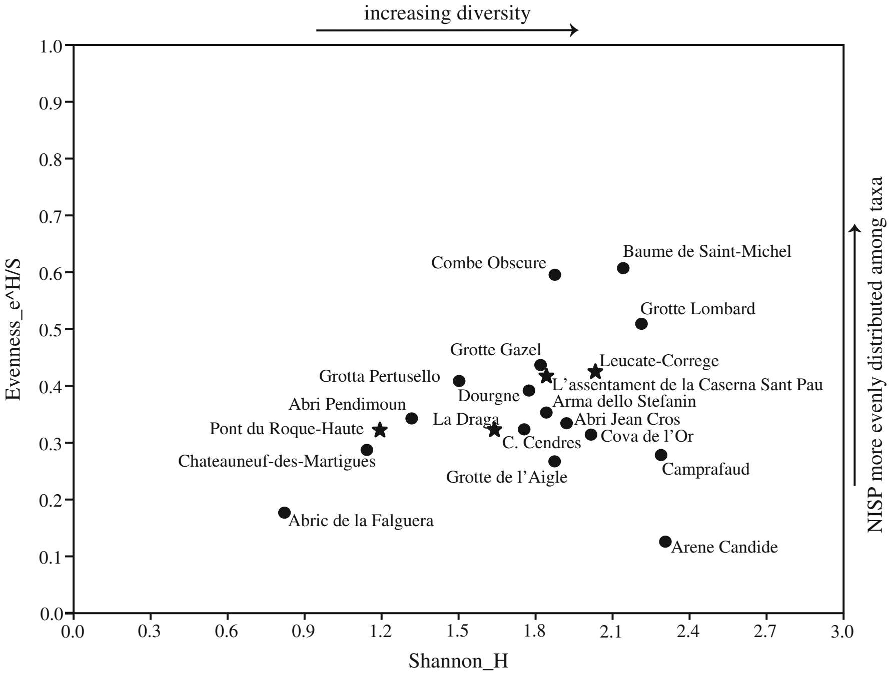

Fig. 9.5 Shannon H diversity measure and evenness index for caves and rockshelters (*circles*) and villages (*stars*) analyzed in this study

A value of 0 in the Shannon-Weaver diversity index indicates an assemblage composed of a single species, whereas higher values capture the presence of 1) more taxa and 2) differences in their abundances. In other words, an assemblage with an even distribution of abundance between taxa has a higher diversity than an assemblage with the same number of taxa but high abundances of a few of them (Reitz and Wing 2008). Assemblage evenness is further investigated by standardizing Shannon-Weaver diversity values to the natural log of the number of species encountered, placing diversity values on a scale of evenness ranging from 0 (very heterogeneous) to 1 (perfectly homogenous). These indices are used to understand the significance of one species relative to others in archaeological assemblages. These measures are used here to assess the degree of similarity in Early Neolithic faunal assemblages drawn from the Western Mediterranean.

As can be seen in Fig. 9.5, the sites captured in this analysis vary in the Shannon-Weaver diversity index, ranging from Abric de la Falguera (0.8279) to Arene Candide (2.309). The evenness measure ranges between 0.129 at Arene Candide, the most heterogenous assemblage in this analysis, and Baume de Saint-Michel (0.61), the most homogenous assemblage. This site is a good example of the differences in diversity captured by these two measures: Baume de Saint-Michel has among the highest diversity levels as measured by the Shannon-Weaver index (2.145), but it is also the most homogenous assemblage studied. In other words, Baume de Saint-Michel's assemblage is more evenly distributed between its 11 taxonomic groups. In contrast, Abric de la Falguera has a higher number of taxa represented ($n = 14$; Table 9.2), but the assemblage is dominated by a few taxa, resulting in a lower Shannon-Weaver index. This is also captured in the evenness measure, where Abric de la Falguera at 0.176 is much more heterogenous than Baume de Saint-Michel. The indices presented here clearly highlight variations in assemblage diversity and evenness among cave/rockshelter sites as well as among villages. In the case of villages, sites differ in the number of taxa represented in the assemblage and in their Shannon-Weaver index, but are similar in their evenness. This suggests that despite taxonomic diversity at these sites, they are dominated by certain species, specifically domesticates (see Fig. 9.6a). Variations in assemblages are also evident in other quantitative measures such as rarefaction analysis discussed below.

9.4.2 Domesticates

Clearly one of the defining factors of Neolithic lifeways in the Western Mediterranean is the engagement with domesticated animals (sheep, goat, cattle, pig, and dog). Not surprisingly, many domestic species are identified in assemblages at all sites in the sample; however, the relative proportions of domesticates to wild species illustrate important trends (Fig. 9.6a). First, many cave and rockshelter sites included in this study have higher proportions of domestic animal remains than nearby open-air villages where one might expect longer, more consistent, occupations, and the bulk of animals to be managed and processed. Instead, the dominance of domestic livestock in cave and rockshelter assemblages suggests a reliance on herds pastured near upland cave and rockshelter sites rather than hunting. Second, the Catalan village sites (La Draga and L'assentament de la Caserna de Sant Pau) have the highest proportion of domesticates in the region, indicating a different pattern of wild game exploitation than observed in village sites in Languedoc. Furthermore, even caves and rockshelters that exhibit a high taxonomic diversity, such as Arene Candide, may be dominated by domestic mammalian remains, while others (e.g., Abri Pendimoun, Abric de la Falguera, Dourgne) are dominated by wild fauna indicating different management strategies or site functions. Although the abundance of wild animal remains is a good indicator of taxonomic diversity (Fig. 9.6b; $p = 0.0001345$), sample size only accounts for 56% of the variation. This suggests that the diversity of wild species in assemblages is only partly influenced by sample size, including at sites dominated by the four primary domesticates.

When we analyze the domestic fauna more specifically, we see differences in livestock composition between site assemblages. Not all sites distinguished between domestic and wild species of cattle (*Bos*) or pigs (*Sus*). As a result, those sites were omitted from the following analysis. In addition, since differentiating osteologically between sheep and goat is particularly challenging and applicable

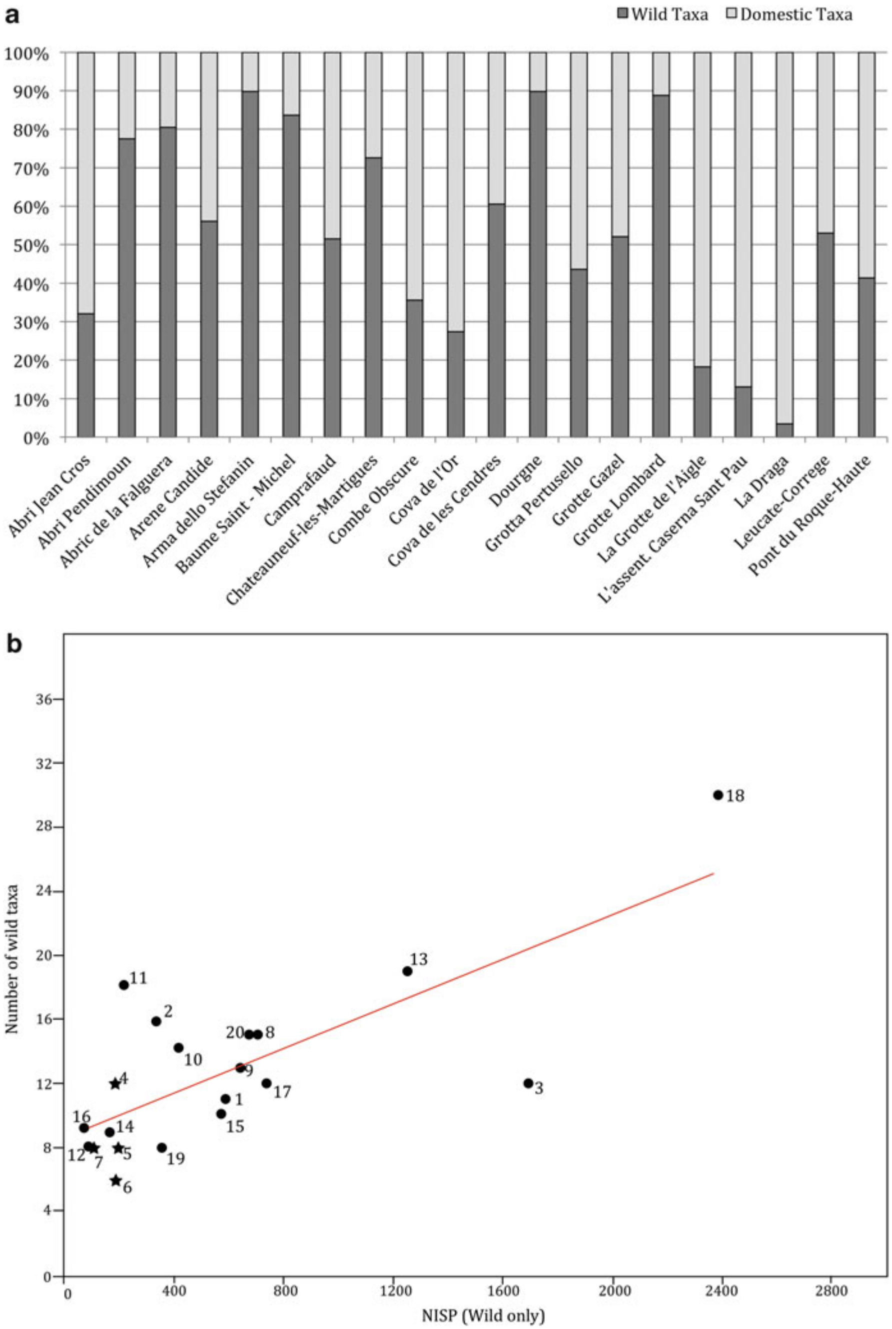

Fig. 9.6 (**a**) Relative percentage of domesticated vs. wild taxa from cave and rockshelter sites (*circles*) and villages (*stars*) analyzed in this study. (**b**) Relationship between sample size and number of wild taxa represented when domesticates are taken out of the analysis. Sites: (*1*) Abric de la Falguera; (*2*) Cova de l'Or; (*3*) Cova de les Cendres; (*4*) La Draga; (*5*) L'Assentament de la Caserna de Sant Pau; (*6*) Pont de Roque-Haute; (*7*) Leucate-Corrège; (*8*) Dourgne; (*9*) Abri Jean-Cros; (*10*) Grotte Gazel; (*11*) Grotte de l'Aigle; (*12*) Combe Obscure; (*13*) Camprafaud; (*14*) Abri Pendimoun; (*15*) Chateauneuf-les-Martigues; (*16*) Baume Saint-Michel; (*17*) Grotte Lombard; (*18*) Arene Candide; (*19*) Grotta Pertusello; (*20*) Arma dello Stefanin

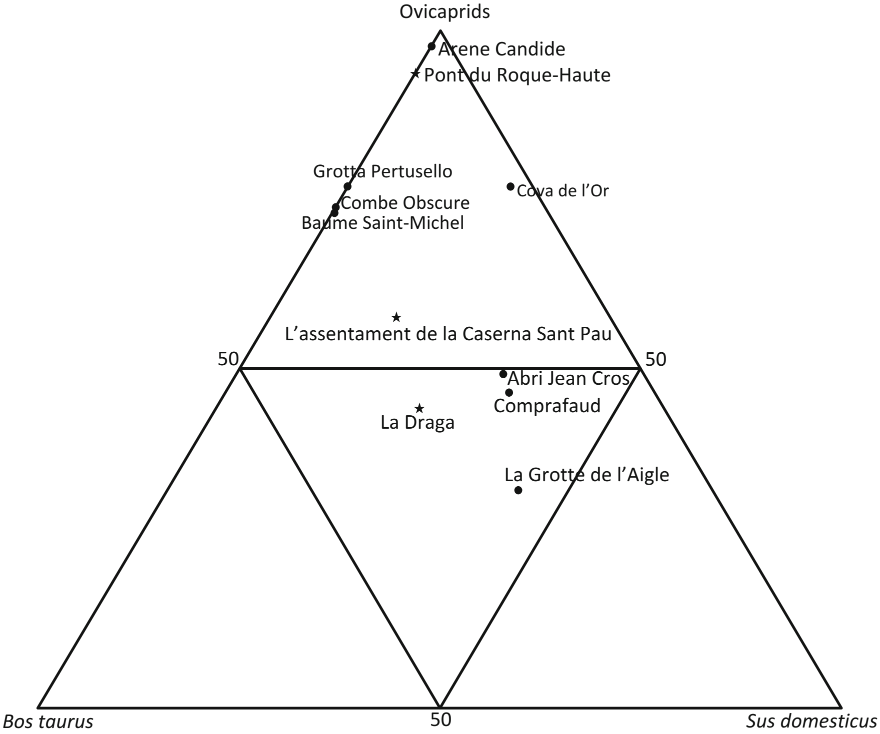

Fig. 9.7 Ternary plot of relative percentages of domesticated species at caves/rockshelters (*circles*) and villages (*stars*) in the Western Mediterranean

only on select elements, these animals were grouped into an "ovicaprid" category. Figure 9.7 graphically presents the relative proportions of cattle, pigs, and sheep/goats at 11 sites from this study. The villages differ in livestock proportions. The Catalan sites, La Draga and L'assentament de la Caserna Sant Pau, fall close to the middle of the ternary plot, indicating a diverse domestic livestock management strategy at these sites. In contrast, the domestic fauna assemblage at Pont de Roque-Haute consists almost entirely of ovicaprids. Differences are greater among the cave and rockshelters as they vary in the relative proportions of each of the domesticates.

Not surprisingly, domestic animal management practices differed depending on site type, i.e., village or cave/rockshelter. What is perhaps more surprising is the degree of variation among villages and among caves/rockshelters. Particularly striking is the lower proportion of ovicaprids in comparison to other sites at Abri Jean Cros, Comprafaud, and La Grotte de l'Aigle, while for the latter, the nearby site Combe Obscure has a much larger proportion of sheep/goats from the same period.

As we have argued so far, the number, diversity, and distribution of species vary between the sites analyzed. In order to assess to what degree this is based on human action, however, we need to further test the notion that differences in assemblages are not the result of sample size but are instead behaviorally meaningful. In the following, we look to another measure of ecological diversity, rarefaction analysis, to assess this question.

9.4.3 Rarefaction Analysis

One way to further explore the assumption that differences in the number of identified taxa at Neolithic sites are the result of sample size and not species use is to employ a single-sample rarefaction analysis (Sanders 1968; Hammer et al. 2001; Lev-Tov et al. 2011). This approach uses the largest assemblage, in this case Arene Candide for the caves/rockshelters and La Draga for the villages, to model the likely number of identified taxa if the sample size were progressively smaller. The results of the modeling are presented as a mean number of taxa expected with its standard deviation at a given sample size. Following Lev-Tov et al. (2011:81–82), we graph these results in Fig. 9.8 and compare the actual number of taxa identified in smaller sample sizes.

Due to differences in available nonmammalian fauna identifications discussed above, we limit the rarefaction analysis to mammals. This helps mitigate inconsistencies in research and reporting practices among sites, although not all inconsistencies, such as the specificity of identifications, are alleviated. In addition, we omit micromammals from the analysis, since information is only available for these animals from half of the sites. Figure 9.8 presents the rarefaction curves for both Arene Candide and La Draga in concert with the sample size and mammalian taxa (no micromammals) distribution of cave/rockshelter and village sites.

The results of this model are interesting: when Arene Candide is used as the basis of rarefaction analysis, four sites (Comprafaud, La Grotte de l'Aigle, Abri Pendimoun, and Baume de Saint-Michel) fall into the 95% confidence interval (Fig. 9.8a). In other words, the number of identified taxa at other sites is well below the expected number based on smaller sample sizes. In turn, when La Draga is used as the starting point for the rarefaction analysis (Fig. 9.8b), seven sites, including village and cave/rockshelter sites, fall within the expected values. Differences in the number of taxa at these sites are within the expected variability based on sample size.

Since La Draga is clearly a farming village, we use it here as a baseline to compare animal use and interaction during the Cardial Neolithic. Not surprisingly, most of the villages fall within the confidence interval range. This indicates that the taxonomic diversity is within the range of model expectations. Similarly, this is also the case for many caves and rockshelters and appears to represent a typical range of taxonomic variation in Cardial Neolithic sites dominated by farming activities. The sites that fall above the rarefaction curve are particularly interesting: Arene Candide, Comprafaud, Grotte de l'Aigle, Grotte Gazel, and Cova de l'Or. The results of this model are likely illustrative of different activities at these sites and those more typical of Cardial Neolithic use, and are discussed in greater detail below.

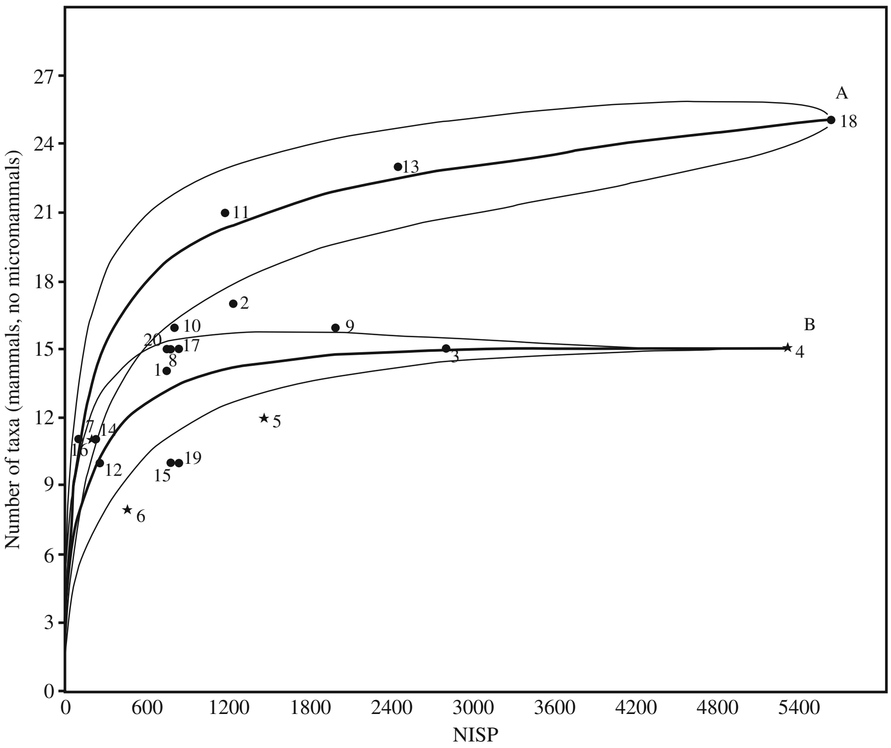

Fig. 9.8 Rarefaction curve (*dark line*) with 95% confidence intervals (*grey lines*) of (**a**) Arene Candide and (**b**) La Draga plotted on the distribution of Number of Identified Specimens (NISP) and number of mammalian taxa (not including micro-mammals) identified in the assemblage. Sites: (*1*) Abric de la Falguera; (*2*) Cova de l'Or; (*3*) Cova de les Cendres; (*4*) La Draga; (*5*) L'Assentament de la Caserna de Sant Pau; (*6*) Pont de Roque-Haute; (*7*) Leucate-Corrège; (*8*) Dourgne; (*9*) Abri Jean-Cros; (*10*) Grotte Gazel; (*11*) Grotte de l'Aigle; (*12*) Combe Obscure; (*13*) Camprafaud; (*14*) Abri Pendimoun; (*15*) Chateauneuf-les-Martigues; (*16*) Baume Saint-Michel; (*17*) Grotte Lombard; (*18*) Arene Candide; (*19*) Grotta Pertusello; (*20*) Arma dello Stefanin

9.5 Discussion and Conclusions

People and animals interacted in many ways during the Neolithic (Russell 2011; Robb 2007; Marciniak 2005). As archaeologists we tend to focus on questions of subsistence—how much did early farmers rely on wild or domestic animals—and occasionally on other economic issues such as the role of leather, pelts, or "secondary" products. In this chapter, we attempt a different approach, focused on the potential of archaeological bone assemblages for ecological research. By approaching the data available for key sites in the Western Mediterranean from this perspective, we believe that we can address several key issues.

All measures presented above demonstrate a degree of variation between sites that is not—or largely not—sample size dependent. However, the link between variation in assemblages and differences in human behavior is not necessarily straightforward. An analyst's confidence in identifications, sample fragmentation, and reporting traditions clearly plays a role in this variation. We have attempted to address these issues here by showing that sample size alone is not enough to explain the degree of variation in taxonomic diversity (Figs. 9.2, 9.3, 9.4, and 9.8). Furthermore, some analysts may be more conservative in their species attribution of specific fragments; however the presence or absence of a species in the whole assemblage is unlikely to vary greatly among studies. Differences in reporting traditions may create difficulties in comparing assemblages, but as we have shown here, basic "laundry list" data are usually available and can be collated effectively (see Scholarsphere database).

Differentiating human from nonhuman deposits is not always straightforward and rarely clearly reported. Many of the cave and rockshelter sites in this study include species such as bats and voles that are likely not representative of human activities, and reflect the activities of nonhuman predators, or nonhuman use of the site. This has led some authors to disregard all small animals from their analyses to focus on the clearly *human* activity in the assemblage (see Rowley-Conwy et al. 2013). As in their overview of Neolithic sites in southern France and Italy, this approach is useful to address specific kinds of questions. However, looking at the entire assemblage enables researchers to investigate other issues related to human-environmental interactions, and we conducted our analysis on data subsets that included or excluded micro-mammals (e.g., bats, voles, mice). With this approach we hope to provide data that can assess the nature of archaeological deposits at these sites and the degree of human and nonhuman use.

The rarefaction analysis of these assemblages presented in Fig. 9.8 delineates four distinct groups (see Table 9.3): (1) villages and cave/rockshelters comparable to La Draga (Cova de les Cendres, Grotte Lombard, Dourgne, Abric de la Falguera, Abri Pendimoun, Leucate-Correge, Arma dello Stefanin); (2) caves/rockshelters with high numbers of taxa that are comparable to Arene Candide (Comprafaud, La Grotte de l'Aigle); (3) caves/rockshelters that fall between Arene Candide and La Draga rarefaction curves (Abri Jean Cros, Cova de l'Or, Grotte Gazel); and (4) village and cave/rockshelter sites that fall below the La Draga rarefaction expectations (L'assentament de la Caserna Sant Pau, Grotta Pertusello, Chateauneuf-les-Martigues, Pont du Roque-Haute).

First, La Draga has the largest, best preserved animal assemblage from a Cardial Neolithic village. If we use La Draga as a baseline for our expectations of Cardial Neolithic animal use by early farming populations, we can begin to look more closely at the other sites in this analysis. As seen in Fig. 9.8b, a number of cave/rockshelter sites meet the expectations of the rarefaction analysis for the Cardial Neolithic (i.e., fall within the 95% confidence interval): Cova de les Cendres, Abric de la Falguera, Dourgne, Grotte Lombard, Arma dello Stefanin, Abri Pendimoun, Combe Obscure, and Baume de Saint-Michel. In other words, the taxonomic diversity at these sites is within the expectations given sample size for La Draga. Despite differences in evenness and relative percentage of domesticates at these sites (Figs. 9.5 and 9.6), they fall into what may be conceptualized as a Cardial

Table 9.3 Sites identified by rarefaction group and associated characteristics

Group	Characteristics	Sites
Group 1	Cardial Neolithic "standard" based on La Draga assemblage	La Draga
		Cova de les Cendres
		Grotte Lombard
		Dourgne
		Abric de la Falguera
		Abri Pendimoun
		Leucate-Correge
		Arma dello Stefanin
Group 2	High number of taxa	Arene Candide
		Comprafaud
		La Grotte de l'Aigle
Group 3	Higher number of taxa than Group 1, but lower than Group 2	Abri Jean Cros
		Cova de l'Or
		Grotte Gazel
Group 4	Lowest number of taxa	L'assentament de la Caserna Sant Pau
		Grotta Pertusello
		Chateauneuf-les-Martigues
		Pont du Roque-Haute

Neolithic "standard"—i.e., a baseline of early farmers using these sites within a basic food-producing economy, and the breadth of wild and domestic animals they interacted with.

Second, Arene Candide has long been known to have a comprehensive and vast faunal assemblage with a great diversity of species represented. However, Comprafaud and La Grotte de l'Aigle fall within the 95% confidence interval of the Arene Candide rarefaction curve, suggesting that the number of taxa represented in these assemblages is what is expected with their sample size (Fig. 9.8a). This indicates that the species diversity is greater at these sites than the Cardial Neolithic standard—i.e., there are more taxa represented at these cave and rockshelter sites than at others in the analysis than expected from sample size alone.

Third, although not within the Arene Candide group, another set of caves and rockshelters exceed expectations based on the La Draga rarefaction. These Group 3 sites exhibit a greater number of taxa than one would expect from the La Draga rarefaction, but fewer than from the Arene Candide analysis. It is an intermediate group between these two measures. Finally, rarefaction analysis also identified village and cave/rockshelter sites falling below the rarefaction curve for La Draga, indicating a more limited suite of taxa in their assemblages (e.g., Grotta Pertusello, L'assentament de Sant Pau, Chateauneuf-les-Martigues, Pont du Roque-Haute).

These four groups are based on their position in the rarefaction analysis and we suggest that differences in human behavior and local ecologies may account for this variation. The decreased diversity in Group 4 sites could be a signal for the increasing size of agricultural and pastoral niches surrounding these sites and the more intensive use of those niches by early farmers and pastoralists. In contrast, we hypothesize that the Arene Candide group represents sites with a greater taxonomic diversity resulting from a combination of people using the area more sporadically and larger numbers of nonhuman predators contributing to the assemblages. In addition, we suggest that these areas were farther from emerging agricultural niches and human occupants were able to garner more diverse resources. These suggestions can be tested in the future by looking at rarefaction analyses diachronically in these regions to see how agricultural infilling affected species diversity in faunal assemblages.

Furthermore, taxonomic variation in this analysis is not limited to wild animals or certain site types. The distribution of domesticates as presented in Fig. 9.7 is illustrative of this point. Although critiques have been made about the viability of comparing cave and rockshelter site assemblages with villages elsewhere (McClure et al. 2014), the data presented here indicate a varied approach to livestock management by Cardial farmers regardless of site type. Even caves and rockshelters, where we would expect pastoral activity resulting in a dominance of ovicaprids, have a greater diversity of livestock species than we anticipated. Also interesting is the very low number of dogs (*Canis familiaris*) at all of the Cardial Neolithic sites in this analysis (see Table 9.2). Remains of domestic dogs are generally rare in Neolithic Europe (e.g., De Grossi Mazzorin and Tagliacozzo 1997; Clark 2006). Despite the assumption that domestic dogs were companions to Neolithic farming populations, the absolute number of remains is very low and in all cases more wild cats (*Felis silvestris*) were found at these sites than domestic dogs. These data may suggest that dogs were not exploited for food or fur after death unlike elsewhere (e.g., Piper et al. 2014), were present in Neolithic communities in small numbers, or their bodies were disposed of differently than other animals during this period.

Comparing taxonomic "laundry lists" between sites also provides insights into non-subsistence interactions between Cardial farmers and animals. Badgers (*Meles meles*), martens (*Martes* sp.), foxes (*Vulpes vulpes*), and wild cats (*Felis silvestris*, *Lynx* sp.) are common to all Cardial Neolithic sites, although they tend to occur in low numbers. Their presence at these sites may be testimony to their utility as fur-bearing animals (e.g., Geddes 1980), attraction to anthropogenic environments, or use of sites when humans were absent. Species variation in martens (*Martes martes* vs. *Martes foina*) indicates differences in density of surrounding woodlands, while remains of species now endangered wild cats (e.g., *Felis silvestris*, *Lynx* sp.) can be used to help understand the evolutionary history of these animals, their distributions through time, and likelihood of their survival in the future (e.g., Vegas-Vilarrubia et al. 2011).

Finally, some of the variation found in these sites could be due to differences in chronology and spread of farming and pastoralism throughout Europe. We chose to focus on the Cardial Neolithic as a means to assess early farmer-animal interactions in the region. However, the spread of farming throughout the Western Mediterranean is by no means linear nor was it likely a single process. New large-scale chronological work is helping define the periodicity of the spread of farming into the Western Mediterranean and will help delineate chronological features in future research on human-animal interactions (e.g., Bernabeu Auban et al. 2014a, b, 2015; Pardo Gordó 2015). In particular, post-Cardial changes in human-animal interactions are documented in shifting animal management strategies at some locations (e.g., Bernabeu Auban et al. 2014a; b; García Puchol and Aura Tortosa 2006). Using a similar approach as presented here, a diachronic analysis will highlight variability in economic activity and local ecologies between sites, including the spread of agricultural niches, impacts on local fauna, and differences in regional site use through time.

Regional studies in recent years have broadened our understanding of the spread of farming in Europe (e.g., Bernabeu Auban et al. 2015; Colledge et al. 2013; Greenfield and Arnold 2015; McClure 2013; Orton 2012; Pardo Gordó 2015; Rowley-Conwy et al. 2013; Saña 2013; Shennan 2009; Vigne 2007; Zeder 2008, 2015). Our analysis of assemblage diversity at several Cardial Neolithic sites indicates a variety of human-animal interactions and livestock management strategies in the Western Mediterranean. Seasonal pastoral mobility is documented throughout the region, although the degree to which researchers interpret these movements as seasonal transhumance of sheep and goats between villages and pastoral stations in caves/rockshelters, or as evidence for an alternative subsistence strategy focused on combined domestic and wild animal exploitation, varies (see Saña 2013).

The variation in faunal assemblages from this time period is worthy of analysis and begs for new work integrating land use, animal management, and ecological histories within local and regional frameworks. These topics can be addressed with appropriate data sets in the future. This analysis was possible thanks to the diligent work of zooarchaeologists in the region over more than 50 years. It is our hope that future work will incorporate increasingly standardized reporting procedures and accessible online databases to help future researchers ask new questions with this unique and valuable archaeological data.

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Part IV
Dietary Subsistence of Early Farming Communities

Chapter 10
Dietary Practices at the Onset of the Neolithic in the Western Mediterranean Revealed Using a Combined Biomarker and Isotopic Approach

Cynthianne Spiteri, Italo M. Muntoni, and Oliver E. Craig

10.1 Introduction

The onset of agriculture is one of the most important milestones to be reached by humans, as far as demographic and economic development is concerned. It allowed communities to sustain an increased population, and ultimately revolutionised the way humans use their environment and lived. How agriculture came about and what triggered the shift from food procurement to food production is still a much debated topic. Many theories have been proposed, including climate change (e.g. Childe 1936; Hayden 1981), population growth (see Smith 1976; Cohen 1977; Hassan 1981; Rosenberg 1998), as well as changes in social and cultural values (see Hayden 1995; Bender 1978; Hodder 1992; Cauvin 2000; Tilley 1996). This shift in subsistence eventually spread worldwide, and decades of research have proposed various models to explain the mechanism by which it spread.

The current model proposed to explain the expansion of farming in the Western Mediterranean suggests that this was a punctuated event, brought about by

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seafaring farming communities (Zilhão 2001). This view is supported by radiocarbon dates obtained from domestic plants and animals found along costal sites from Italy to Portugal, which are statistically indistinguishable and cluster around 5500 cal. BC (Zilhão 2001). At this time, characteristic Impressed/Cardial pottery and domesticates appear contemporaneously on Mediterranean coastal sites. Pottery has for a long time been perceived as an indicator of agrarian settlements. In fact, its association with farming communities was widely accepted until evidence for the production of ceramic vessels was identified in hunter-gatherer communities in Asia and the Russian Far East, dating back to the Pleistocene (e.g. Jordan and Zvelebil 2010 and references therein). This therefore questions whether there is in fact a direct association between Impressed/Cardial Wares and domesticates, despite their contemporaneous chronological attestations at the onset of the Neolithic in the Western Mediterranean, as it is also possible to hypothesise that Impressed/Cardial Wares could have been spread by highly mobile hunter-gatherer-fishing communities. The key to understanding the link between Impressed/Cardial Wares and farming in the Mediterranean, and therefore also how these ceramics were spread, is to identify the contents, hence function, of these vessels.

ORA is a well-established technique, which has been routinely used to characterise a wide range of animal products (e.g. ruminant and non-ruminant adipose, ruminant dairy products, marine/freshwater oils and fat), plant oils and epicuticular waxes, beeswax, bitumen, wine, resins and tars present in archaeological artefacts (see reviews Debono Spiteri et al. 2011; Regert 2011; Evershed 2008b). The premise for using ORA is that when animal and plant products are processed in unglazed ceramics, the heat generated will cause the fatty components in these commodities to become absorbed within the ceramic walls (Heron and Evershed 1993). These absorbed lipid residues can be extracted and characterised; hence the contents of individual vessels can be identified. This, in turn, establishes a direct link to vessel use (Evershed et al. 1999). Residues from charred visible crusts, which are sometimes found adhered to the surface of ceramic vessels, can also be similarly extracted and characterised (e.g. Craig et al. 2013). Gas chromatography (GC), gas chromatography-mass spectrometry (GC-MS) and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS) are the main analytical instruments used to characterise lipid residues. GC analysis is used to separate out and quantify the lipids present in the extracted residue, while GC-MS provides structural information on these lipid constituents, which allows a preliminary identification of the source material to be made by identifying key biomarkers. GC-c-IRMS analysis measures the $^{13}C/^{12}C$ of two particular fatty acids, palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) fatty acids, denoted as $\delta^{13}C$ values. The $\delta^{13}C$ measurements of these two fatty acids vary in different fatty products because of variation in the way they are biosynthesised and routed within the organism, which in turn allows different fats to be categorically distinguished. Distinction between ruminant and non-ruminant adipose, and ruminant adipose and dairy fats, whose lipid profiles are too similar to permit a secure characterisation using GC and GC-MS analysis is made possible (Evershed et al. 2002). $C_{16:0}$ and $C_{18:0}$ fatty acids are present in all living organisms, their $\delta^{13}C$ values are not affected by diagenesis over archaeological timescales (Evershed et al. 1999), and they are readily extractable from prehistoric pottery, making these two fatty acids excellent compounds to target for GC-c-IRMS analysis.

Most of the work carried out on Impressed/Cardial Wares has focussed on their chronological appearance and spread, their form, decorative styles and manufacture. Function has, however, only tentatively been discussed, and has been attributed mainly in terms of the size, form and level of decoration. Pottery played a fundamental role in the development of cuisine and the transformation of food. It facilitated the adoption of new foodstuffs, such as cereals, and enabled a wider diversification of food combinations, while certain types of food could also be more intensely used and transformed, and used over a greater part of the year (Ingold 1983; Manson 1995). Identifying the contents of Impressed/Cardial Wares could potentially allow a better understanding of their role at the transition to agriculture. This chapter, which is part of a wider study in which over 500 Impressed/Cardial Ware vessels recovered from 21 Early to Middle Neolithic sites in the Mediterranean were tested (Spiteri et al. 2011–2012, Debono Spiteri et al. 2016), considers the function of Impressed/Cardial Wares in the Western Mediterranean, and tests their association with agro-pastoral communities through the application of ORA. This is crucial to understand the link between the spread of these ceramic wares and farming in this region.

10.2 Impressed/Cardial Wares

Impressed/Cardial Wares are among the earliest types of pottery to appear in the Mediterranean region. The type-ware describes their distinctive decorative motifs, comprising a wide array of impressions created using fingers, fingernails and other small instruments (*Impressa/Impresso* Wares), and/or impressions made by using the edges of the *Cerastoderma edule* L. (*Cardium*) and *Glycymeris insubricus* Broc. shells (Cardial Wares), in the soft, unfired clay (Spataro 2009). *Impressa* decorations are generally associated with the eastern and central Mediterranean, up to the Ligurian coast of Italy, although Cardial impressions are well documented in Italy. Similarly, Cardial Wares tend to dominate in the Western Mediterranean, though Impressa decorations were also used (Barnett 2000). Early pottery was divided into two main categories, coarse and fine wares, the former possibly used for cooking, while the latter appears to have been used in the consumption of specific foods and drinks (Tiné 2002). The differences between the two categories were not simply aesthetic (e.g. different styles of surface finishing), but sometimes structural (e.g. the type of temper used, which may have played a significant role in the functional properties of the vessels produced) (Pessina 2002). They had rather simple shapes, comprising hemispherical and conical bowls, large deep vessels, cups and more rarely bi-conical vessels and necked flasks (Muntoni 2009; Spataro 2009). These wares were influenced by local customs, but they also spread very rapidly across the Mediterranean area (Gheorghiu 2008). In fact, pottery is one of the best known aspects of the Impressed Ware culture (Spataro 2011), and it is still considered an indicator of these farming communities and the major means of investigating their way of life (Muntoni 2002).

10.3 Materials and Methods Section

Analysis was carried out on 301 Impressed/Cardial Wares pertaining to both the coarse and fine ware traditions, with a broad selection of surface treatment including characteristic impressed decorations, and undecorated and burnished sherds. Vessel shape was often difficult to identify, but the assemblage analysed comprised a selection of rims, bases and body fragments from ceramic vessels associated with cooking, serving and perhaps storage of food commodities. All sherds were obtained from domestic contexts. Impressed/Cardial Wares from 14 sites spread across the Western Mediterranean were selected (Fig. 10.1 and Table 10.1 with relative bibliographic references) .

The methodology is reported in Debono Spiteri et al. (2016), and followed established protocols (e.g. Craig et al. 2011). Sampling was carried out using a Dremmel modelling drill with a tungsten bit. About 2 g of ceramic powder was drilled from the internal surface of each sherd to a depth of around 4 mm, discarding the first layer to remove possible contamination introduced by handling and contact

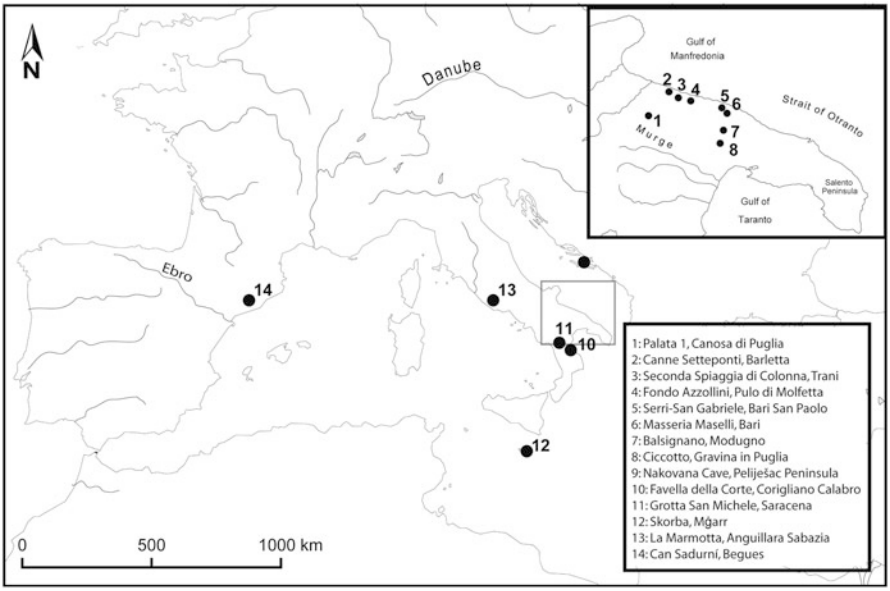

Fig. 10.1 Map showing the location of the sites included in the study [map reproduced with modifications from Debono Spiteri et al. 2016]

Table 10.1 Table listing the site details and associated number of Impressed/Cardial Ware vessels tested together with their respective lipid yields

Site	Phase	Calibrated date (cal BC, 2σ)		Inland/Coastal[a]	Site type	Total number of vessels analysed	Total number of vessels containing >5 μg g^{-1} lipid	Lipid concentration max/mean (μg g^{-1})
Fondo Azzollini, Pulo di Molfetta	EN	6100–5880	Radina (2006b)	Coastal	Open-air settlement	25	20	3662.8/247.9
Ciccotto, Gravigna in Puglia	EN	No date	Muntoni (2003)	Inland	Open-air settlement	15	7	221.4/22.9
Ciccotto, Gravigna in Puglia	MN	No date		Inland	Open-air settlement	10	3	9.0/3.6
Palata 1, Canosa di Puglia	EN	5616–5582	Radina et al. (2011)	Inland	Open-air settlement	39	5	8.8/1.8
Balsignano, Modugno	EN	5600–5450	Radina (2002)	Inland	Open-air settlement	35	2	13.0/1.8
Serri-San Gabriele, Bari—San Paolo	EN	No date	Radina (2009)	Coastal	Open-air settlement	15	–	–/–
Masseria Maselli	EN	5620–5380	Radina (2006a)	Coastal	Open-air settlement	12	–	–/–
Seconda Spiaggia di Colonna, Trani	MN	5051–4849	Fiorentino et al. (2013)	Coastal	Open-air settlement	26	1	7.3/–
Canne Sette Ponti, Barletta	MN	No date	Radina (2003)	Coastal	Open-air settlement	12	–	–/–
Favella della Corte, Corigliano Calabro	EN	6000–5700	Tinè (2009)	Coastal	Open-air settlement	27	4	8.7/2.2

(continued)

Table 10.1 (continued)

Site	Phase	Calibrated date (cal BC, 2σ)		Inland/ Coastal[a]	Site type	Total number of vessels analysed	Total number of vessels containing >5 μg g^{-1} lipid	Lipid concentration max/mean (μg g^{-1})
Grotta San Michele, Saracena	EN	5840–5610	Tinè and Natali (2011–2012)	Inland	Rockshelter	4	2	24.3/7.8
Grotta San Michele, Saracena	SW	No date		Inland	Rockshelter	11	9	17.5/6.2
La Marmotta, Anguillara Sabazia	EN	5865–4997	Fugazzola Delpino (2002), Fugazzola Delpino (in press)	Coastal	Open-air settlement, submerged	6	–	–/–
Skorba	EN	5500–3650	Fenech (2007)	Coastal	Open-air settlement	5	1	5.4/–
Skorba	TP	4350–3050		Coastal	Open-air settlement	11	–	–/–
Nakovana Cave	EN	5980–5550	Forenbaher et al. (2013)	Coastal	Rockshelter	8	7	18.8/10.5
Nakovana Cave	MN	5310–4790		Coastal	Rockshelter	9	8	247.1/39.4
Can Sadurní	Cardial	5394–5313	Martín et al. (2010)	Inland	Rockshelter	12	3	80.2/8.6
Can Sadurní	EPC	4988–4773	Blasco et al. (2005)	Inland	Rockshelter	17	9	460.0/79.6
Can Sadurní	PC	4180–4037	Edo et al. (2011)	Inland	Rockshelter	2	1	150.7/–

[a] <6 km from coast

Data obtained from Debono Spiteri et al. 2016

EN early Neolithic, *MN* middle Neolithic, *SW* stamped ware, *TP* temple period, *EPC* epi-cardial, *PC* post-cardial with plastic. External surfaces were also sampled to test for exogenous contamination. The ceramic powder was accurately weighed and 1 μg tetratricontane was added as an internal standard for quantification purposes. Lipids were extracted three times by sonicating in a mixture of dichloromethane and methanol (2:1; *v:v*) (HPLC grade; Fischer). Following centrifugation, the solvent was pipetted off into clean screw-capped vials, and then evaporated under a gentle stream of nitrogen and mild heating to obtain the total lipid extract (TLE), which was then partitioned (50%). Prior to high-temperature-GC-FID (HT-GC-FID) and GC-MS analyses, one-half of the partitioned lipid extracts was derivatised using N,O-bis (trimethylsilyl)trifluoroacetamide (BSTFA) with 1% trimethylchlorosilane (TMCS) (four drops; 70 °C; 1 h).

Twenty-seven samples contained sufficient $C_{16:0}$ and $C_{18:0}$ fatty acids for GC-c-IRMS analysis. To release esterified fatty acids, the remaining TLE was saponified by adding 0.5 M sodium hydroxide solution made up in a methanol and water solution (9:1, v:v), and heating at 70 °C for 1 h. The samples were allowed to cool, and then neutralised. The lipids were extracted into hexane (Fischer; HPLC grade), and the solvent was gently evaporated. Saponification was also carried out on a selection of the extracted ceramic powder samples to analyse the 'bound' lipid fraction not released by solvent extraction.

Fatty acid methyl esters (FAMEs) were prepared using 200 μL of boron trifluoride methanol solution (14%; Sigma Life Science) and heating for 1 h at 70 °C. The FAMEs were extracted into hexane and the solvent reduced. $C_{16:0}$ and $C_{18:0}$ fatty acid standards of known carbon isotopic composition were methylated alongside the samples, and were later used to correct the $\delta^{13}C$ values obtained for the carbon atom added during methylation. The samples was analysed using GC-FID, GC-MS in scanning and selective ion monitoring (SIM) mode and GC-c-IRMS.

10.4 Overview of the Results Obtained Using ORA

Out of the 301 Impressed/Cardial Wares analysed, 81 yielded a significant residue and 220 vessels contained negligible amounts of lipid (<5 μg lipid per gram of sherd) (Debono Spiteri et al. 2016), which cannot be securely distinguished from background contamination (Evershed 2008a). Saponification of the extracted ceramic powder to release the 'bound' lipid fraction produced negligible results. This high incidence of low lipid yield also precluded observations related to the use of pottery over time, which was why both Early and Middle Neolithic ceramics had been sampled. The highest percentage of significant lipid yields were obtained from the cave sites, Nakovana Cave (94%), Grotta San Michele (73%) and Can Sadurní (42%), but two of the open-air settlements, Pulo di Molfetta (Fondo Azzollini) and Ciccotto, also yielded a good proportion of vessels which contained significant quantities of lipid residues (80% and 40%, respectively) (Table 10.1, Fig. 10.2).

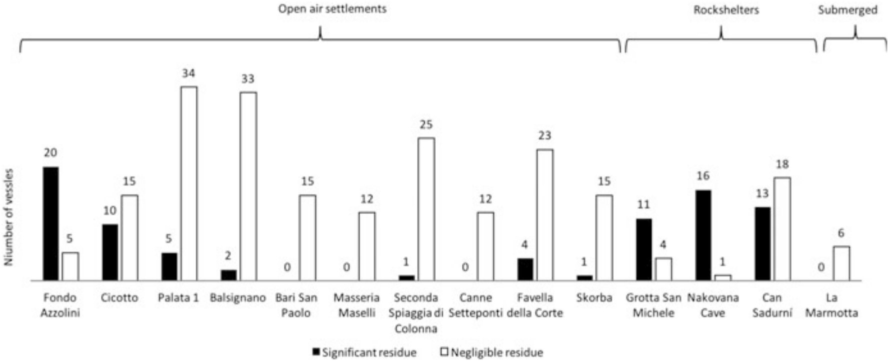

Fig. 10.2 Bar chart showing the number of vessels containing significant and negligible lipid residues from each of the sites included in the study [data obtained from Debono Spiteri et al. 2016]

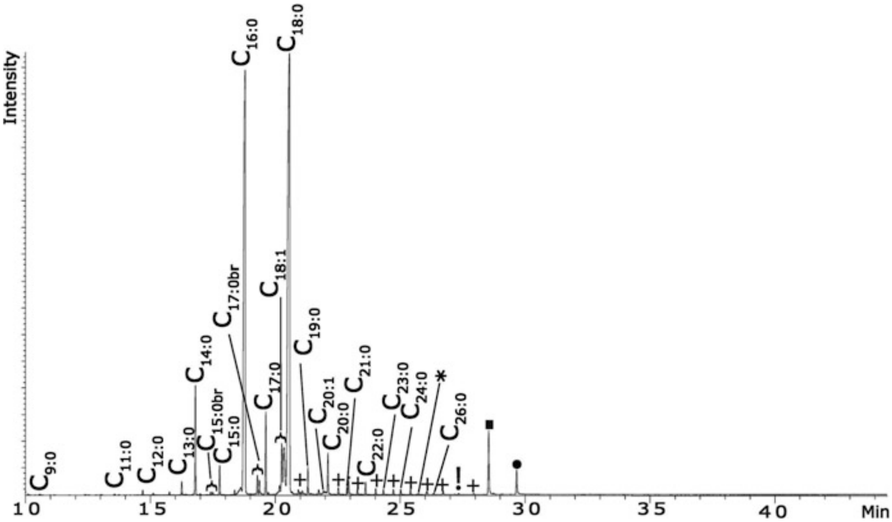

Fig. 10.3 Total ion chromatogram (TIC) of an Early Neolithic coarse ware bowl recovered from Fondo Azzollini identified by GC-c-IRMS as containing a ruminant dairy residue. [Cx:y: Fatty acid where x is the carbon number and y is the degree of unsaturation; (*plus*) alkanes (C23–C33); (*asterisk*) alcohols (C26); (*exclamation mark*) cholesterol; (*filled square*) internal standard (C34); (*filled circle*) internal standard (C36)]

Total lipid extracts were mostly consistent with degraded animal fats, comprising mainly $C_{16:0}$ and $C_{18:0}$ fatty acids, the latter generally being more abundant (Fig. 10.3). A ruminant origin is suggested by the presence of branched-chain fatty acids ($C_{15:0}$ and $C_{17:0}$), produced by microorganisms in the rumen (Keeney et al. 1962). Cholesterol and its dehydration products (e.g. cholesta-3,5-diene) were often identified, and are indicative of animal fats (Debono Spiteri et al. 2016). HT-GC-

FID also revealed the presence of triacylglycerols in residues extracted from several sites including Pulo di Molfetta (Fondo Azzollini), Ciccotto, Grotta San Michele, Nakovana Cave and Can Sadurní, indicating good lipid preservation, which is consistent with the lipid yields obtained from these sites. Di- and monoacylglycerols, degradation products obtained from the hydrolysis of triacylglycerols, were also frequently present. Long-chain ketones derived from the condensation of fatty acids during heating and indicative of cooking (criteria consistent with Raven et al. 1997) were identified in several vessels recovered from Pulo di Molfetta (Fondo Azzollini), Ciccotto, Trani—Seconda Spiaggia di Colonna, Nakovana Cave and Can Sadurní.

A considerable number of vessels contained a significant residue, but lacked sufficient quantities of $C_{16:0}$ and $C_{18:0}$ for GC-c-IRMS analysis. Consequently, only 27 samples could be submitted for GC-c-IRMS analysis (Debono Spiteri et al. 2016). Archaeological fats were interpreted against a global database of reference fats including specimens from the target area. Ruminant adipose reference fats also take into consideration wild ruminant species (deer), which were published by Craig et al. (2012). This was necessary since at Can Sadurní and Pulo di Molfetta (Fondo Azzollini) deer bones were found in the faunal assemblage, albeit at low frequencies. Combining domestic and wild ruminant adipose isotopic values ensured a comprehensive range for the ruminant adipose category. The isotopic measurements obtained indicate primarily the use of terrestrial fats, and allowed identification of porcine and ruminant adipose, and dairy fats (Table 10.2, Fig. 10.4). Interestingly, the $\delta^{13}C$ values of the $C_{16:0}$ fatty acids in three of the samples, one each from Pulo di Molfetta (Fondo Azzollini), Skorba and Can Sadurní, plotted within the isotopic range denoting marine oils. This shift towards more positive values could be due to a contribution from C_4 vegetation (e.g. maize or sorghum), or marine oil. Research to date has shown that C_4 plants had not yet been introduced in the Mediterranean during the Neolithic (Hunt et al. 2008), so these residues could potentially represent a mixture comprising ruminant fat and marine oil. However, marine fish biomarkers were not present in the lipid profiles of these three samples despite SIM analysis, either because they were not preserved or because fish had not been processed in the pots in the first place. Moreover, fish bones were not recorded in the archaeological deposits at these sites, which further preclude a secure identification for the use of marine products.

Mixtures of animal and plant products were identified in 13 vessels recovered from several sites, including Pulo di Molfetta (Fondo Azzollini), Palata 1, Grotta San Michele, Nakovana Cave and Can Sadurní. Two of the animal fat inputs in these mixtures were identified by GC-c-IRMS as dairy fats, and three were similarly identified as ruminant adipose. Plant inputs, separately and in mixtures, were indicated by the presence of phytosterols (plant sterols) and palmitate wax esters, known components of the plant cuticle (Evershed 2008b), as well as criteria outlined in Copley et al. (2005b, 2001b).

Table 10.2 List of the morphological details of the 27 sherds submitted for GC-c-IRMS analysis, the different classes of lipids identified using HT-GC and GC-MS and the isotopic measurements obtained

Lab. Code	Site	Phase	Vessel shape	Vessel part	Decoration	Lipid quant. (μg g^{-1})	Lipid classes present	$\delta^{13}C_{16:0}$ (‰)	$\delta^{13}C_{18:0}$ (‰)	$\Delta^{13}C$ (‰)
AZZ-11I	AZZ	EN	Jar	Base	Impressed	27.01	FFA	−28.4	−28.8	−0.5
AZZ-13I	AZZ	EN	Jar	Rim	Impressed	129.7	FFA, ALC, TAG, C	−24.3	−28.4	−4.1
AZZ-14I	AZZ	EN	Jar	Rim	Impressed	17.06	FFA, ALC, DAG, K, C	−28.0	−28.1	−0.2
AZZ-18I	AZZ	EN	Jar	Base	Impressed	292.65	FFA, ALC, MAG, DAG, TAG, C	−30.0	−30.7	−0.7
AZZ-23I	AZZ	EN	Carinated bowl	Rim	Burnished	1550.28	FFA, ALC, TAG, K	−27.6	−31.8	−4.2
AZZ-25I	AZZ	EN	Carinated bowl	Rim	Burnished	343.46	FFA, ALC	−26.9	−30.7	−3.8
AZZ-26I	AZZ	EN	Bowl	Rim	Und.	3662.82	FFA, ALC, MAG, TAG, K, C, WE	−27.5	−29.4	−1.9
AZZ-31I	AZZ	EN	Jar	Perforated rim	Impressed	35.57	FFA, ALC, MAG, DAG, C	−30.8	−30.6	0.2
AZZ-35I	AZZ	EN	Jar	Body	Burnished	11.22	FFA, ALC	−27.6	−30.9	−3.4
CIC-12I	CIC	EN	Jar	Body	Impressed	52.74	FFA	−30.7	−33.5	−2.8
CIC-13I	CIC	EN	Jar	Body	Impressed	18.1	FFA, ALC, K	−31.5	−31.4	0.1
CIC-14I	CIC	EN	Jar	Body	Impressed	221.42	FFA, K	−28.4	−33.1	−4.7
TRA-16I	TRA	MN	Small jar	Base	Und.	7.33	FFA, ALC, MAG, DAG, TAG	−28.1	−32.3	−4.2
SAR-02IA	SAR	EN	Jar	Rim	Impressed	13.09	FFA, ALC, DAG, C, WE	−29.1	−30.2	−1.1
SAR-09AI	SAR	SW	Bowl	Rim	Impressed & incised	8.35	FFA, ALC, DAG, TAG	−27.5	−31.9	−4.3
SAR-11AI	SAR	SW	Collared jar	Rim	Incised	14.79	FFA, ALC, C, WE	−28.1	−32.5	−4.4
SKR-16I	SKR	EN	Bowl (?)	Body	Und.	5.44	FFA, ALC, DAG, K	−23.4	−26.5	−3.1

NAK-04I	NAK	EN	Globular bowl/jar	Body	Burnished	16.45	FFA, ALC, MAG, DAG, TAG, C	−25.8	−26.7	−0.9
NAK-07I	NAK	EN	Globular bowl/jar	Body	Burnished	18.83	FFA, K	−27.9	−32.8	−5.0
NAK-08I	NAK	MN	Globular bowl/jar	Body	Und.	247.07	FFA, ALC, K	−27.2	−32.4	−5.1
NAK-12I	NAK	MN	Globular bowl/jar	Body	Und.	66.98	FFA, ALC, K, C	−27.9	−32.5	−4.6
CNS-0IE	CNS	Cardial	Unknown	Body	Und.	32.6	FFA, ALC, K, WE	−25.2	−27.1	−1.9
CNS-03I	CNS	Cardial	Unknown	Body	Und.	8.85	FFA, ALC, DAG, K	−29.0	−33.4	−4.4
CNS-06I	CNS	EPC	Unknown	Body	Und.	460.01	FFA	−23.6	−27.1	−3.5
CNS-10I	CNS	EPC	Unknown	Body	Smoothened	136.93	FFA, ALC, MAG, DAG, TAG, K, C, WE	−27.2	−30.5	−3.3
CNS-11I	CNS	EPC	Unknown	Body	Und.	414.49	FFA, ALC, DAG, TAG, K, C, WE	−26.7	−29.1	−2.4
CNS-13	CNS	EPC	Unknown	Body	Und.	11.42	FFA, K	−24.8	−28.2	−3.4

Data obtained from Debono Spiteri et al. 2016

EN early Neolithic, *MN* middle Neolithic *SW* stamped ware, *EPC* epi-cardial, *FFA* free fatty acids, *ALC* alcohols, *K* ketones, *MAG* monoacylglycerols, *DAG* diacylglycerols, *TAG* triacylglycerols, *WE* wax ester, *C* cholesterol, *AZZ* Pulo di Molfetta (Fondo Azzollini), *CIC* Ciccotto, *TRA* Trani—Seconda Spiaggia di Colonna, *SAR* Grotta San Michele, *NAK* Nakovana Cave, *SKR* Skorba, *CNS* Can Sadurní

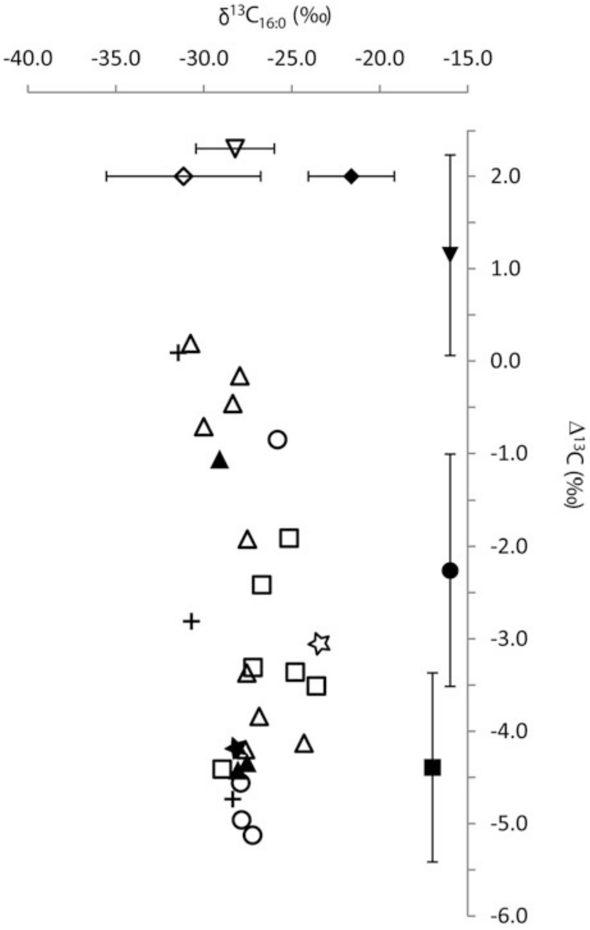

Fig. 10.4 Plot of mean $\delta^{13}C_{16:0}$ against mean $\Delta^{13}C$ ($\delta^{13}C_{18:0}$–$\delta^{13}C_{16:0}$). Reference points plot the mean values obtained from authentic modern animal fats in published literature (Craig et al. 2012, 2005, 2007; Dudd 1999; Gregg et al. 2009) and have been supplemented with data from the milk and blood from sheep ($n = 2$), cows ($n = 2$), and pigs ($n = 2$) raised on C_3 Mediterranean grown plants, and fish ($n = 6$) caught from Mediterranean waters. All modern values have been corrected for post-industrial carbon (1.2%; Friedli et al. 1986). There error bars denote ±1‰ standard deviation. The distribution of archaeological residues plotting within the different fat categories is quite wide, in particular the dairy samples. This is attributed to intra-site variation, which was observed in bulk stable carbon analysis carried out by Lelli et al. (2012), who noted up to a 2.1% variation in the $\delta^{13}C$ of the terrestrial fauna analysed. Evershed et al. (2008) also observed a wide $\delta^{13}C$ range for the $C_{16:0}$ fatty acids, and attributed this to the inclusion in the diet of water-stressed plants, which are known to affect the $\delta^{13}C$ measurements of the organisms feeding on them (Tieszen 1991). This represents a likely scenario in the Mediterranean, which could also cause the wide distribution of the measurements obtained [(*filled diamond*) marine fats/oils; (*open downward triangle*) terrestrial fat; (*open diamond*) freshwater fish; (*filled downward triangle*) wild and domestic porcine fats; (*filled circle*) wild and domestic ruminant adipose; (*filled square*) ruminant dairy fat; (*open upward triangle*) Pulo di Molfetta (Fondo Azzollini); (*plus*) Ciccotto; (*filled star*) Trani—Seconda Spiaggia di Colonna; (*filled downward triangle*) Grotta San Michele; (*open circle*) Nakovana Cave, (*open star*): Skorba; (*open square*) Can Sadurní] [data obtained from Debono Spiteri et al. 2016]

10.5 Lipid Preservation Issues in the Mediterranean

Organic residues are more likely to survive in waterlogged and desiccated environments (Regert et al. 1998; Copley et al. 2005b), rather than in areas where seasonal variations alternate between heavy rainfall and hot dry spells (Evershed et al. 2008; Gregg et al. 2009). The climate in the Mediterranean is more consistent with the latter. Moreover, all the sites investigated lie on calcareous deposits, which are not conducive to the survival of lipid residues mainly because they support a richer microbial population than acidic environments, enhancing lipid degradation (Moucawi et al. 1981). Hence the climatic conditions and burial contexts would have played a significant role in the poor lipid yields extracted from the Impressed/Cardial Wares analysed, and this appears to be supported by the high percentage of lipid residues recovered from vessels deposited in cave sites (namely Grotta San Michele, Nakovana Cave and Can Sadurní), which are more sheltered from the seasonal cycles (Fig. 10.2). However, the ceramic assemblages analysed from the open-air sites at Pulo di Molfetta (Fondo Azzollini) and Ciccotto in Apulia yielded good quantities of absorbed lipid residues, particularly at Fondo Azzollini, where 80% of the ceramics analysed retained a significant quantity of residue. This suggests that perhaps the burial context is not the only factor leading to the low lipid yields obtained and other scenarios must be considered which may not have been conducive to the formation of a residue during the use-life of a vessel. Possible factors could be the porosity of the ceramic fabric, which is crucial for lipid absorption during use and which likely negatively affected the La Marmotta ceramics. These ceramic vessels were extremely solid and difficult to sample and therefore unlikely to have absorbed much lipid during their use-life, which was unfortunate because the submerged context of this site held excellent potential for lipid preservation. The fat/oil content of the product contained within the vessels and the frequency of use would also affect whether or not a residue is likely to form and survive in the archaeological record. For example, it is unlikely that sufficient quantities of lipid will become absorbed in serving dishes which are not repeatedly used and only briefly in contact with fatty products, or storage vessels used to store plant products such as grains. Indeed experimental work has shown that very low quantities of plant oils become absorbed within the walls of ceramic vessels when processing plant material (Evershed et al. 1995), and plant residues are easily masked by fattier products if these are cooked simultaneously with plant products or in separate cooking episodes (Reber and Evershed 2004; Evershed 2008a). While specific biomarkers for particular plant groups have been identified (e.g. Evershed et al. 1991; Copley et al. 2005b), the degraded lipid profiles of most plant residues are indistinguishable from background contamination. Consequently, plant oils are very often under-represented, unless preservation conditions permit a secure identification (Dunne et al. 2012; Copley et al. 2005b, 2001a, b). Therefore, although taphonomy plays a major role in decay and loss of lipid residues, negligible yields can indeed be brought about by anthropogenic use, and could potentially be significant to understanding vessel use.

10.6 Plant Use in the Early Mediterranean Neolithic Diet

Plant remains have been heavily attested in most of the sites included here. Archaeobotanical remains on the Murge Plateau provide evidence for extensive cereal cultivation during the Neolithic (Fiorentino 2002; Fiorentino et al. 2013), while evidence for the use of cultigens has been preserved in the archaeological record at La Marmotta, Favella della Corte, Grotta San Michele and, in particular, Layer 18 at Can Sadurní, where ceramic vessels containing cereal grains were found. Only two sites, Nakovana Cave and Skorba, showed limited evidence for plant remains. Nakovana Cave is thought to have been used by pastoralists to shelter herds, and the surrounding environment is not suitable for cultivation. However evidence for plant use was obtained using ORA, which identified mixtures of plant and animal contributions in six of the vessels analysed. Ceramic vessels containing food products could potentially have been transported to the cave from nearby hamlets, where the surrounding arable land could have been used to grow cultigens. At Skorba, botanical evidence is supported by only a few charred grains (Trump 1966); however, this does not preclude a thriving cultivation practice, since floatation was not used during excavations, and plant remains are likely to be under-represented.

Out of the 81 significant residues extracted from the Impressed/Cardial Ware assemblage submitted for ORA, 10 were tentatively attributed to plant contributions based on the quantity of lipid extracted (low but $>5\ \mu g\ g^{-1}$) and the lipid profiles obtained, which generally comprised low levels of $C_{16:0}$ and $C_{18:0}$ with a palmitic-to-stearic fatty acid ratio >4, which has been shown to be indicative of plant residues (Copley et al. 2005b), a wide series of alkanes and alcohols as well as the occasional presence of phytosterols and wax esters. A plant contribution was further identified in another 13 vessels, as mixtures with animal products (Fig. 10.5). Whether the high percentage of negligible residues pertains to a plant contribution is not known. However, the archaeobotanical evidence retrieved from the various sites and palaeodietary data carried out, in particular in the Apulian region (Scattarella and Sublimi Saponetti 2002; Lelli et al. 2012), appear to support a heavy reliance on plant material during the Neolithic.

10.7 Animal Products in the Early Mediterranean Neolithic Diet

Animal products were identified in 24% of the ceramic vessels analysed, and in 9 of the 14 sites investigated (Fig. 10.5) (Debono Spiteri et al. 2016). These comprised ruminant and non-ruminant adipose, and ruminant dairy products, which were also identified as mixtures with plant oils, suggesting simultaneous cooking of animal and plant products (e.g. in stews or broths), or re-utilisation of Impressed/Cardial Ware vessels. Ruminant fats are the most widely represented in the lipid-rich sites,

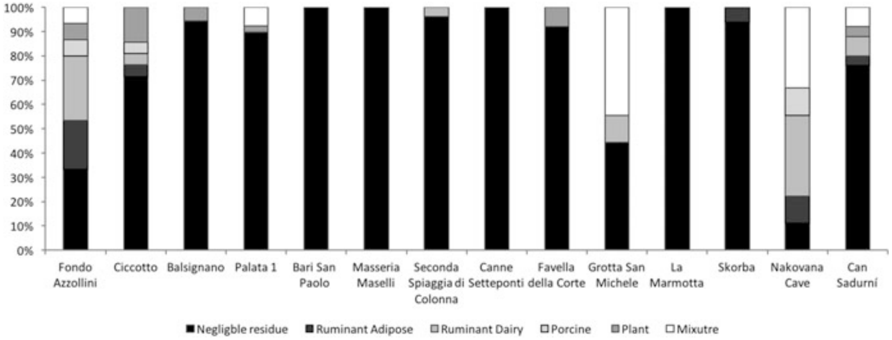

Fig. 10.5 Bar chart showing the percentage distribution of food products identified in the Impressed/Cardial Ware vessels tested using GC-MS and GC-c-IRMS analysis. [The ruminant fat category includes residues identified as ruminant adipose fats by GC-c-IRMS analysis. The rest of the vessels included in this category show characteristic lipid profiles for degraded ruminant fats, but in the absence of sufficient quantities $C_{16:0}$ and $C_{18:0}$ fatty acids could not be further discriminated.] [Data obtained from Debono Spiteri et al. 2016]

with at least 4% of the total number of ceramic vessels analysed being securely found to contain dairy fats. Most of the faunal assemblages recovered from the sites investigated were either too fragmented to allow an in-depth analysis or are still in the process of being studied. However, when available, a predominance of ruminant animal remains was found, dominated by ovicaprids, which consistently made up over 69% of the faunal remains recovered at the different sites investigated (e.g. as identified in various sites located on the Murge Plateau in Apulia, Italy (Wilkens 2002), and at Can Sadurní in Catalonia (Saña et al. 2016). Cattle remains were generally less abundant, as were pig bones. Research carried out by Mirabaud et al. (2007) has shown that using ORA, it is possible to distinguish between cow and goat dairy products, and sheep and cow adipose fats, by analysing the fatty acid distribution of residual triacylglycerols. In this study, triacylglycerols were unfortunately identified only in trace amounts, which precluded further analysis. Ruminant fats comprised the highest percentage of animal residues identified in Impressed/Cardial Ware vessels, which is consistent with the faunal records studied to date. Non-ruminant fats were also identified following GC-c-IRMS analysis in two Impressed Ware jars from Pulo di Molfetta (Fondo Azzollini) and Ciccotto (Debono Spiteri et al. 2016), which is also consistent with the retrieval of domestic pig bone in several Early Neolithic sites in the Murge region (Wilkens 2002). Hunting, especially of roe and red deer, is known to have continued during the Early Neolithic, as recorded in the faunal assemblages recovered from the Murge area (Wilkens 2002) and at Can Sadurní (Saña et al. 2016), but appears to be sporadic given the low quantities of deer bone found at these sites. This suggests that the four residues whose isotopic measurements plot within the area of overlap between ruminant adipose and dairy products are likely to be remnants of the latter (Fig. 10.4).

10.7.1 The Production and Consumption of Dairy Products

The onset of dairying was until more recently thought to have occurred towards the end of the Neolithic. Sherratt's (1981, 1983) concept of a 'secondary products revolution' suggested that during the Early Neolithic, sheep, goat and cattle were mainly utilised for their primary products (meat, bone and hide), with a limited use of their secondary products (milk, traction and wool), which however intensified towards the end of the Neolithic, around the fourth millennium BC in the Near East and the third millennium BC in Europe. This theory has since been revised. Vigne and Hemler's (2007) study on faunal remains recovered from several sites in the Near East and the Mediterranean (including southern France, Italy and the Balkans) suggested that dairying was already practiced at the earliest stages of the Neolithic, starting from the early eighth millennium BC (mid-PPNB) in the Near East, and the mid-sixth millennium BC in Mediterranean Europe. This finding was complemented soon after by ORA analysis, which unequivocally proved that dairy products were processed in pottery vessels dated to the seventh millennium BC in the Near East and Anatolia (Evershed et al. 2008). Other applications of ORA have also established the presence of dairy residues in Early Neolithic ceramics excavated from sites located in Europe (Craig et al. 2005; Salque et al. 2012; Copley et al. 2005a, 2003; Cramp et al. 2014a), and the Libyan Sahara (Dunne et al. 2012). An early start date for the use of dairy products can also be asserted in the Mediterranean (Debono Spiteri et al. 2016). Dairy residues identified in Impressed Wares dating to 6100–5880 cal. BC at the Apulian settlement of Pulo di Molfetta (Fondo Azzollini) provide the earliest dates for the use of milk products in the Western Mediterranean, while dairy residues identified in Cardial Wares at Can Sadurní affirm the practice of dairying since the earliest phases of the Neolithic on the Iberian Peninsula (5475–5305 cal. BC; Blasco et al. 2005). The identification of dairy residues in Early Neolithic contexts in Croatia, Catalonia and other sites in the Apulian and Calabrian regions of Italy suggests a widespread use of dairy products from the onset of the Neolithic in the Mediterranean (Debono Spiteri et al. 2016).

The identification of dairy products also securely ties in the function of Impressed/Cardial Wares with agrarian practices. Experimental re-constructions have shown that domesticates could indeed have been transported in boats (Broodbank and Strasser 1991), evidence for which has been found at La Marmotta in Italy (Fugazzola Delpino 2002). Rowley-Conwy (2011) suggested that dairy products may have played a crucial role in the survival of pioneer farming communities spreading throughout the Western Mediterranean, especially during the first year of settlement. The nutritional value of milk is well known and could potentially tide struggling communities over seasons of low productivity. Furthermore, the ability to process milk provides the added advantage of storing surplus dairy products (e.g. as cheese, yoghurt and butter) making them available all year round (Evershed et al. 2008), and also allows lactose-intolerant people to consume dairy products (Ingram et al. 2009). Dairy products could therefore have been crucial to the survival of early settlers. A gene-culture co-evolution between humans and cattle in Europe was identified by Beja-Pereira et al. (2003), but research conducted by Burger et al. (2007) (supported by subsequent studies, e.g. Itan et al. 2010; Plantinga et al. 2012; Gerbault et al. 2011) suggests that 8000 years ago, milk consumption in Europe could not have been widespread, since the allele responsible for digesting lactose, 13.910*T, was absent. This contrasts the comparatively early evidence obtained, using both faunal analysis and ORA, for pastoral practices in Europe and the Mediterranean, which suggests that selection for lactase persistence (LP) was underway. In the Mediterranean, LP is still attested at low frequencies compared to Northern Europe (Ingram et al. 2009). How this came to be, and what the LP frequency was like during the Early Neolithic, is currently driving much of the current research.

10.8 The Absence of Marine Products in the Early Mediterranean Neolithic Diet

The extent of human dependence on marine products, in particular at the transition to agriculture, has been widely researched and debated. Stable carbon and nitrogen isotope analysis has consistently shown a dietary shift, from a predominantly marine to a terrestrial diet during the Mesolithic-Neolithic transition in the United Kingdom and Scandinavia (Schulting and Richards 2002; Richards et al. 2003; Lidén et al. 2004). Stable carbon and nitrogen analysis applied to Mediterranean Neolithic contexts at Arene Candide (Liguria, Italy) and Pendimoun (southern France) (Le Bras-Gaude et al. 2006), Fontbrégoua, also in southern France (Le - Bras-Goude et al. 2010), Montou in the Pyrenees (Le Bras-Gaude and Claustre 2009), and in several other Early Neolithic sites along the Croatian coast (including Pupiĉina, Grapčeva and Crono Vrlo) (Lightfoot et al. 2011) also appears to suggest a departure from the inclusion of marine food sources during the Neolithic. Moreover, little or no evidence for fish bones has been found in the archaeological deposits at these sites, which could however be potentially due to preservation issues. Stable isotope analysis carried out on eight skeletons excavated from the Brochtorff Circle in Gozo (Malta) showed no evidence for a marine input (Richards et al. 2001), as at Alepotrypa Cave, Franchthi and Kephala in Greece (Papathanasiou 2003; Papathanasiou et al. 2000). All these sites are located within easy reach of the Mediterranean Sea, except Fontbrégoua which lies about 100 km inland. Stable isotope analyses carried out on skeletons recovered from various sites in the Marche, Tavoliere and Murge regions of Italy (Lelli et al. 2012), some of which (Balsignano, Masseria Maselli and Palata 1) were also investigated in this research, showed a small but significant marine input in humans buried along the Apulian and Marche coastal areas, whereas limited or no evidence was obtained for a marine contribution to the dietary requirements of individuals buried further inland.

Using Hawkes and O'Connell's (1992) and Winterhalder's (1993) discussion on optimal foraging theory, Richards and Schulting (2006) suggest that compared to agrarian practice, fishing is more time consuming and does not produce high yield returns. Hence, although the sea was an available resource, Neolithic communities were more likely to subsist on the more efficient and productive activities of terrestrial produce (Richards and Schulting 2006). While acknowledging the logic behind this argument, Craig et al.'s (2011) research showed that at the transition to agriculture in the Baltic, marine resources were still an important dietary component, which therefore reopens the issue as to whether this apparent underuse of an available resource during the Neolithic is in fact a cultural choice, or whether the research methods applied to date are perhaps not sensitive enough to detect a marine signal. This issue has already been widely debated in terms of bias in the zooarchaeological record, the number of human bone collagen samples analysed to date which have been used to infer the dietary composition of a population, as well as the efficiency of the stable isotope method used (Hedges 2004; Milner et al. 2006, 2004; Richards and Schulting 2006).

The residues extracted from the three Impressed/Cardial Ware vessels at Pulo di Molfetta (Fondo Azzollini), Skorba and Can Sadurní that showed higher $\delta^{13}C$ values for their $C_{16:0}$ fatty acids could, in the absence of C_4 vegetation, be indicative of a fish origin (Debono Spiteri et al. 2016). However, fish biomarkers, which would have securely identified the processing of fish products (Cramp et al. 2014b; Craig et al. 2011; Heron et al. 2010; Hansel et al. 2004), were not present, and it could only be tentatively suggested that perhaps these residues originated from mixed fish and terrestrial products. ORA results therefore suggest a limited use of marine products during the Early Neolithic in the Mediterranean. Of course, pottery vessels are not always used to cook fish; however despite floatation methods used at most sites, fish bones were remarkably scarce, with none being identified in most of the sites included in this research, except at Favella della Corte and La Marmotta. It is difficult to perceive why people would 'turn their backs' on a freely available resource, especially when considering that most of the sites investigated in this research are located within 6 km or less of the Mediterranean coast. Yet only 3 out of the 301 ceramic vessels analysed tentatively suggest a marine input, while a secure characterisation for fish oils could not be made. It must however be noted that the poor lipid yield obtained from the ceramics investigated may have resulted in the marine biomarkers being too depleted to be detected. However, the absence of fish bones in most of the sites included in this study provides no indication that perhaps other cooking/preparation methods had been utilised. When considering that current models for the transition to agriculture in the Mediterranean suggest that these early farmers were seafarers, and hence had a close connection to the sea, the absence of a marine component perhaps indicates a conscious decision to avoid marine food products, in favour of terrestrial produce.

10.9 Vessel Specialisation in Impressed/Cardial Wares

There appears to be no distinct regional patterning in the type of residues identified in Impressed/Cardial Wares, and no variation in use between sites located close to the Mediterranean coast and settlements located further inland. Similar percentages of vessels were found to contain ruminant fats, although ruminant dairy fats were more frequently identified in ceramics recovered further inland, whereas plant residues and mixtures of plant and animal residues were more common on coastal sites (Fig. 10.6a). Fatty residues pertaining to ruminant and porcine adipose, ruminant milk fats and plant products were identified in a variety of vessel shapes, including cooking (e.g. jars) and serving vessels (e.g. bowls), and there appears to be no apparent association between vessel shape and type of products processed within (Fig. 10.6b). No distinctive trends were identified when comparing the ceramic fabric to the type of residue absorbed within, although *Figulina* Wares (present in Middle Neolithic contexts) appear to be associated only with plant remains (Fig. 10.6c). Impressed/Cardial Wares were highly decorated, and it has been suggested that the decorations applied could in fact have had a social significance (Martí-Oliver 2002; Gheorghiu 2008). Decorative motifs could also have been used to identify the contents, hence function of particular vessels. Significant quantities of absorbed fatty residues were identified in sherds bearing impressed decorations, and pots whose surface had been burnished, smoothened or left undecorated (Fig. 10.6d). Mixtures comprising plant and animal residues were also identified in sherds bearing incised and scratched decorations, while none of the sherds bearing cardial and cordon decorations, as well as the red-painted and red-slipped sherds, contained significant quantities of absorbed residue. However, most of the sherds analysed were sampled from highly fragmented assemblages, and therefore not all the sherds classified as ‘undecorated’ necessarily originated from undecorated vessels, and similarly, different decorative techniques could have been applied to the same vessel, which, however, could not be identified in the present research. Hence, interpretations pertaining to associations between food product and decorative motifs are only tentative, and based on the data available at the time of analysis. In light of the results obtained, there appears to be no particular association between decorative motif, and the fatty absorbed residues identified. Impressed/Cardial Ware vessels seem to have been used indiscriminately to process animal and plant products, and their function appears to have been consistent in the different regional contexts investigated within the Mediterranean.

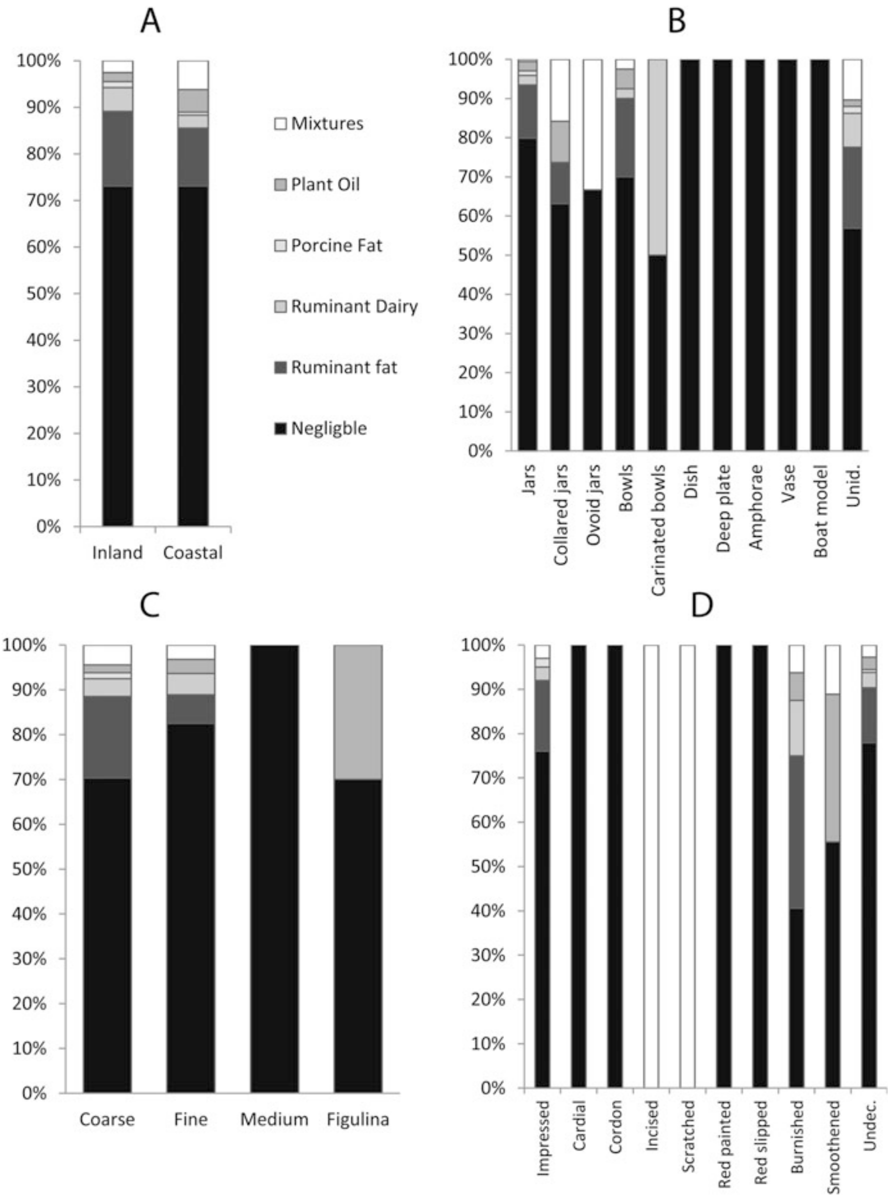

Fig. 10.6 Bar chart showing the percentage attestations of the different food products identified in (**a**) inland/coastal sites, (**b**) different vessel types, (**c**) different types of fabric and (**d**) decorative repertoire [Unid.: unidentified; Undec.: Undecorated] [data obtained from Debono Spiteri et al. 2016]

10.10 Conclusion

Combined biomarker and isotopic techniques confirmed that Impressed/Cardial Wares were used to process ruminant adipose fats and dairy products. Non-ruminant fats and plant oils were also identified, as well as residues containing mixtures of animal fats and plant products. Of particular interest was the absence of marine biomarkers from all the residues extracted, which perhaps suggest a conscious avoidance of marine products in the Early Neolithic diet at the sites investigated. No distinctive trends were observed between the type of absorbed residue identified and the different vessel forms and ceramic fabrics. Similarly, the type of decoration applied to the vessels was not particular to the different food commodities processed within these wares. The function of Impressed/Cardial Wares during the Early Neolithic appears to have been quite homogenous over such a widespread geographical context. The low lipid recovery obtained emphasises the necessity to increase the sample size analysed when applying ORA in Mediterranean contexts, and in no way does it diminish the potential of this technique to inform on the use of ancient pots, and culinary preferences of the communities that produced them.

The identification of dairy residues in Impressed/Cardial Wares provided direct evidence for the widespread use of dairying from the earliest phases of the Neolithic in the Western Mediterranean dating to the late seventh millennium BC. This indicates that the nourishing qualities of dairy products were widely recognised and included in the Early Neolithic diet. The identification of dairy residues in Impressed/Cardial Wares also allowed a direct connection to be made between these ceramic wares and the first agrarian/pastoral communities in this region. Identifying evidence for the use of Impressed/Cardial Wares in pastoral activities directly ties their use to agrarian/herding communities, and suggests that the spread of Impressed/Cardial Wares occurred together with domesticates, by farming communities who arrived in the Western Mediterranean by the late seventh millennium BC.

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Chapter 11
A Terrestrial Diet Close to the Coast: A Case Study from the Neolithic Levels of Nerja Cave (Málaga, Spain)

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11.1 Introduction

The significance of coastal areas with regard to human survival and dispersal is undeniable, due to their ecological diversity and use as communication routes (Bicho and Haws 2011). It has even been suggested that the nutritional content of marine molluscs could have played an important role in the development of cognitive abilities (Erlandson 1988; Hockett and Haws 2003). However, the evidence for the exploitation of these aquatic resources is not preserved universally, but depends on the location of the site with respect to the shifting coastline throughout different time periods (Bailey 2008). Normally, the sites that preserve evidence of the consumption of marine resources are located on the present coastline, or in a range of less than 10 km from it (Bailey 2008). The majority of

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the identified remains are usually invertebrates (molluscs), though fish, bird and mammal bones have also been documented, if less frequently (Aura Tortosa et al. 2016).

In the case of the Mediterranean, it has been argued that the low presence of sea-animal remains in human occupation contexts during prehistoric times is due to its low productivity compared to other seas and oceans, e.g. the Atlantic (Clarke 1976). Most Western Mediterranean sites are caves and rockshelters, located on the same coastline or only a few kilometres apart, so distance to the coast alone is not sufficient to explain the scarce evidence of sea-animal remains. Nerja Cave, having always been close to the sea throughout the Neolithic, is a key site for investigating this issue: proximity to the sea undoubtedly influenced the lives of its inhabitants, and one would imagine that marine resources would be an important part of their diet. During the Late Palaeolithic-Epipalaeolithic and the Mesolithic at Nerja Cave the zooarchaeological studies of mammal, fish and bird remains show a variety of marine resources being both consumed and present in the immediate environment of the cave (Aura Tortosa et al. 2002). This might not necessarily have always been diet-related, as it could also be associated to symbolic expressions as attested clearly by marine faunal depictions (Sanchidrián 1994) or the abundance of marine shell as pendants or containers (Jordá Pardo 1986a) in southern Iberia. In contrast with the pre-Neolithic, the evidence of marine resource procurement is scarce for the Neolithic levels.

We argue that only the combination of palaeobiological, techno-economic, graphic-symbolic and molecular data can ultimately result in a proper assessment of the use of marine resources in the region before and after the onset of the Neolithic.

11.2 Nerja Cave: The Site and Surrounding Environment

Cueva de Nerja—or Nerja Cave—is an archaeological site in southern Iberia (Málaga, Spain) close to the Mediterranean coastline (Fig. 11.1). Discovered in 1959, it is a cave belonging to the Alpujárride complex in the inner Betic Mountains. It has three entrances: two natural ones and a third artificial one opened in 1960. The cave comprises lower, upper and "new" galleries. Archaeological remains, ranging from the end of the Palaeolithic up to the Neolithic, have been found in chambers within the lower galleries. The three main chambers are Mina (NM), Vestíbulo (NV) and Torca (NT), which have been excavated periodically between 1979 and 1987. This study is based on the excavations conducted according to modern standards (i.e. following natural stratigraphic units): those under the direction of Manuel Pellicer (Pellicer and Acosta 1997) in the NM and NT chambers, as well as those carried out under the supervision of Francisco Jordá Cerdá in the NV and NM chambers (Jordá Cerdá 1986a, b).

The deposits from Nerja Cave, which have been excavated by several teams from 1979 until 1987, range from the final stages of the Late Pleistocene

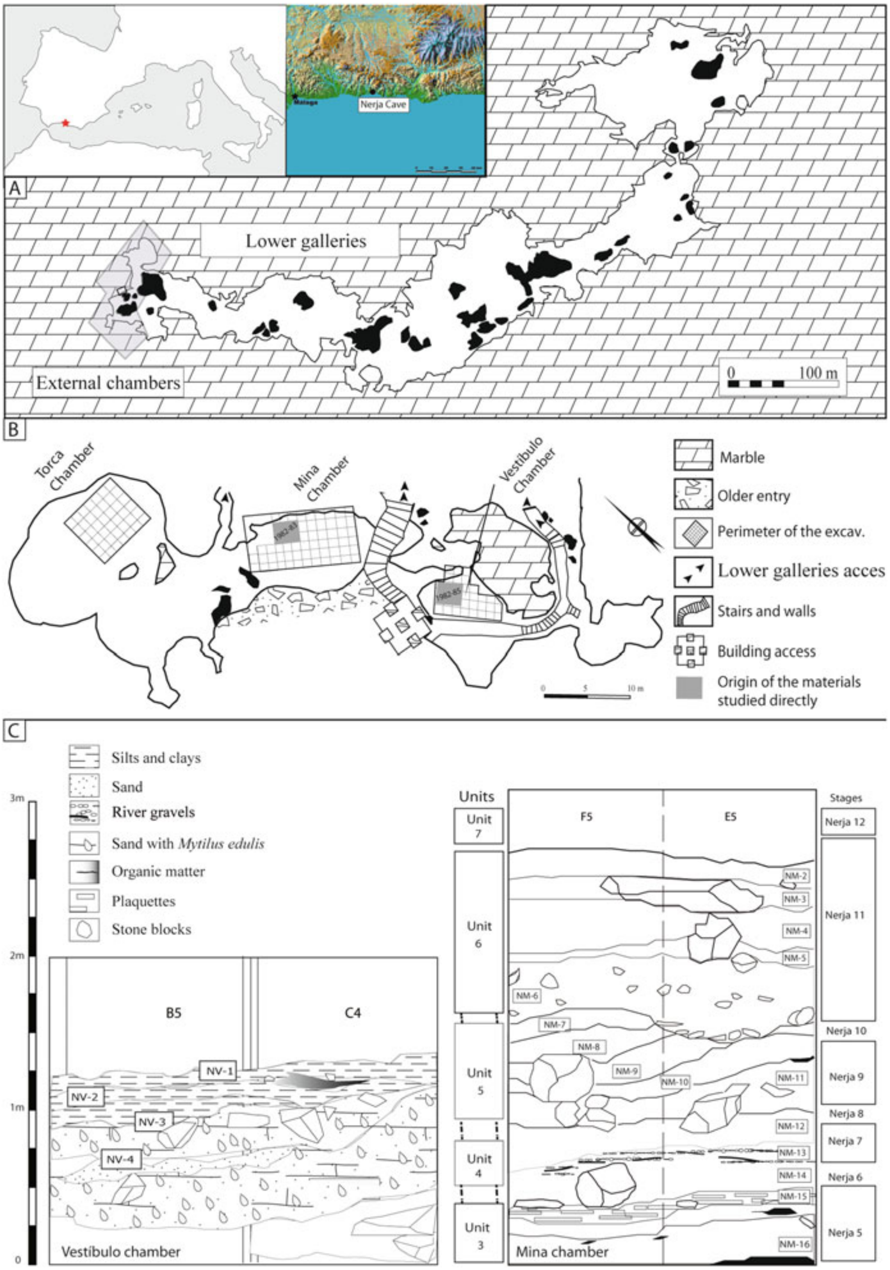

Fig. 11.1 Nerja Cave. (**a**) Location in the Western Mediterranean, (**b**) site plan with excavated areas highlighted, and (**c**) archaeological profiles of the Mina and Vestíbulo chambers, based on those from squares F5/E5 and B5/C4, respectively (modified from Aura et al. 2013)

(Marine Isotope Stage MIS 3) to the mid-Holocene (MIS 1) (Aura Tortosa and Jordá Pardo 2014). The sedimentary sequence, consisting of 12 episodes of sedimentation and erosion—equivalent to seven lithostratigraphic units separated by five stratigraphic discontinuities—was reconstructed by correlating the sequences from NM, NV and NT (Jordá Pardo and Aura Tortosa 2009). Human remains and material culture from both the Mesolithic and the Neolithic periods have been accurately documented at the different levels of the three main chambers (Table 11.1). Human presence at this site during the crucial time of the Neolithic expansion and transition to farming across the Mediterranean (Martí Oliver and Juan-Cabanilles 2014) makes Nerja Cave one of the most important sites in Iberia for the study of dietary ecology.

11.3 Holocene Palaeoenvironment and Stratigraphy

The archaeological sequence of Nerja Cave is closely associated to the past coastline position changes (Jordá Pardo et al. 2011). During the Upper Pleistocene and Early Holocene, the sea level at Nerja Cave was below its current position (Jordá Pardo et al. 2011). During the Neolithic, however, the variations in sea level were minor and the site was almost directly on the coastline. Both the palaeobotanical and palaeofaunal records at this site, considered as palaeoclimatic proxies, indicate a milder Thermo-Mediterranean climatic zone at the end of the human occupation during the Neolithic.

Compared to today, at the beginning of the Holocene the sea level was 23 m lower and the coastline 400 m further away. As a result a wider coastal land corridor, set within a dynamic and rapidly evolving landscape, existed as attested by surveys of southern Iberian river mouths showing an increase in sedimentation during the Holocene (Hoffman and Schultz 1987). Although silting has been linked to increased human activity, the episodes of maximum sedimentation all postdate the occupation of the cave.

The Holocene synthetic stratigraphic sequence was obtained from the correlation of the NM and NV chamber lithostratigraphic sequences (Aura Tortosa et al. 2013; Jordá Pardo 1986a; Jordá Pardo and Aura Tortosa 2009; Jordá Pardo et al. 1990). The NT chamber also preserves evidence of human occupation during the Epipalaeolithic, Mesolithic and Neolithic (Pellicer and Acosta 1997). Radiometric correlation between the NT, NM and NV chamber sequences was obtained on the basis of radiocarbon (AMS) dates, even if the archaeostratigraphic correlation of NT with NM and NV chambers is not straightforward (Sanchidrián and Márquez Alcántara 2006).

Overall, the Holocene sequence at Nerja Cave comprises two lithostratigraphic units (Units 5 and 6) that correspond to two sedimentary stages (Nerja 9 and 11 stages) separated by a stratigraphic discontinuity (Nerja 10 stage). At NM and NV, Unit 5 (Nerja stage 9) lies discontinuously over Unit 4 (Nerja stage 7), the former of which accumulated during the Younger Dryas (Greelnland Stadial 1) at

Table 11.1 Correlation of the sequences defined during the excavations of the Vestíbulo (NV), Mina (NM) and Torca (NT) chambers by the research groups of Jordá Cerdá and Pellicer & Acosta

Period (Date cal BC)	Phase (Date cal BC)	Vestibulo chamber	Mina Chamber				Torca Chamber	
		Jordá	Jordá	Pellicer & Acosta				
		1982-87	1979-87	NM-79	NM-80A	NM-80B	NT-79	NT-82
Recent Neolithic (3700–2900)	Late Neolithic (3700–2900)	nd	NM-2		NM80A-2	NM80B-1, 2, 3	NT79-3	NT82-7
Middle Neolithic (4800–3700)	Middle Neolithic II (4800–3700)	nd	NM-3		NM80A-3	NM80B-4, 5		NT82-8
	Middle Neolithic I (4800–4300)	nd	NM-4 NM-4/5	NM79A-1		NM80B-6		
Early Neolithic (5600-4800)	Recent (5100–4800)	NV-1	NM-5	NM79-1,2	NM80A-4	NM80B-7	NT79-4	NT82-9, 10
	Middle (5300–5100)	NV-2	NM-6 NM-7 NM-8 NM-9	NM79-3, 4, 5		NM80B-8, 9		
	Ancient (5475–5300)	NV-3a-b	NM-10 NM-11	NM79-5?		NM80B-10B		
	Archaic (5600–5475)	NV-3a-b NV-4 (pit)	None	None	None	None		None
Mesolithic (8200–6000)	*Transition* Geometric	NV-3-c?	NM-12?		NM80A-5		*NT79-5*	*NT82-11*
	Flakes & bladelets (ca.8200–7000?)	None	NM12?					
Epipalaeolithic (11000–8200)	Epi-Magdalenian	NV-4.1 NV-4.2	NM-13		NM80A-6		NT79-6, 7	NT82-12

the end of the Late Pleistocene. The stratigraphic discontinuity between the units is defined by an erosive scar and the absence of sedimentation (Nerja stage 8) during most of the Lower Holocene. Unit 5 in NV consists of levels NV3, NV2 and NV1, and in NM of levels NM12 to NM7. The bottom of the Unit contains remains from the Geometric Mesolithic, dated to the Middle Holocene, while the middle and upper parts yielded materials from the impressed Early Neolithic (within the Atlantic chronozone). In the NV excavated area, the sequence is interrupted at the top of NV1, which is an artificial floor generated during the refurbishing of the site as a tourist attraction (Fig. 11.1).

At Nerja Mina, over Unit 5, an erosion surface of low intensity is found, corresponding to stage Nerja 10 and without a relevant impact on the archaeological record. Over this surface is located Unit 6, which comprises levels NM6, NM5 and NM4 (stage Nerja 11) at its base, and the chronology of which spans the Atlantic and Subboreal chronozones. The sequence terminates with Unit 7 (stage Nerja 12), composed of a breccia overlain by a banded speleothem which formed either at the end of the Subboreal or at the start of the Subatlantic periods (Jordá Pardo and Aura Tortosa 2009), during a temperate pulse which is well represented in NM but less so in NV.

The deposits of the Holocene sequence can be associated with low-energy processes (i.e. surface runoffs), produced under warm and humid climatic conditions. However, at the upper part of the sequence high-energy processes were detected (e.g. sheet floods and colluviums), which developed in a warm but drier weather punctuated by torrential rainfall. This pronounced seasonality, with humid and dry moments and sporadic precipitations, coincides with the Neolithic occupation of Nerja Cave. Farming practices can be associated with evidence for the erosion and transportation of materials (including boulders and heterometric sediments) from the cave's exterior to its interior.

The techno-economic data provided by artefacts define the presence of Neolithic horizons on the upper layers of occupation within the cave. However, between the Neolithic and the Mesolithic phases there is a gap of several centuries (~500 years) as shown by the results of radiocarbon dating obtained from Mesolithic materials (botanical and faunal remains) and the oldest Neolithic domestic faunal remains (Table 11.2). This supports the hypothesis that there was no transition process at the site: there is no evidence for autochthonous domestication nor for processes of inculturation/acculturation, at least not of such duration to become part of the archaeological record (Aura Tortosa et al. 2013). The appearance of the Neolithic at Nerja is therefore linked to the East-West pioneer navigation expansion of agriculture and husbandry along the Mediterranean coasts (Martí Oliver 2008; Zilhão 2001).

The combination of the stratigraphic sequences from NM and NV, the radiocarbon dates on domesticates and the archaeological assemblages (wares, lithics, bone tools) were used to propose an organised chronocultural sequence for the episodes of Neolithic occupation at Nerja Cave within the framework of the Western Mediterranean region (García Borja et al. 2014): Early Neolithic (ca. 5600–4800 cal BC), Middle Neolithic (ca. 4800–3700 cal BC) and Late Neolithic (ca. 3700–2900 cal BC). This can be directly related to the framework of the Valencian Neolithic,

Table 11.2 Radiocarbon dates from short-lived samples available for different NM and NV levels of Nerja Cave excavated by Jordá Cerdá

	Level	Identification	ZooMS analysis	Lab. Ref.	^{14}C BP	SD	Cal. BC (p95‰)	Cal. BP (p95‰)
1 (N)	NV-2	*Hordeum vulgare*	–	Beta-284149	5050	40	3990–3710	5940–5660
2 (N)	NM-5	*Ovis*/*Capra*	Indeterminate	OxA-26077	5998	31	4990–4790	6940–6740
3 (N)	NM-5	*Hordeum* sp.	–	Beta-284147	6070	40	5100–4860	7050–6810
4 (N)	NM-5	*Ovis aries*	Indeterminate	OxA-26078	6149	31	5250–4970	7200–6920
5 (N)	NV-2	*Ovis*/*Capra*	–	MAMS-20437	6185	21	5230–5030	7180–6980
6 (N)	NM-6	*Ovis*/*Capra*	*Ovis aries*	OxA-26079	6207	32	5290–5010	7240–6960
7 (N)	NM-7	*Ovis*/*Capra*	Indeterminate	OxA-26080	6196	31	5260–5020	7210–6970
8 (N)	NM-7	*Ovis*/*Capra*	Indeterminate	OxA-26081	6219	33	5330–5010	7280–6960
9 (N)	NM-8	*Ovis*/*Capra*	*Ovis aries*	OxA-26082	6214	35	5330–5010	7280–6960
10 (N)	NM-9	*Ovis*/*Capra*	*Ovis aries*	OxA-26084	6254	33	5320–5160	7270–7110
11 (N)	NV-3	*Ovis aries*	–	Beta-369357	6300	40	5350–5190	7300–7140
12 (N)	NM-10	*Ovis*/*Capra*	Indeterminate	OxA-26085	6342	37	5410–5250	7360–7200
13 (N)	NM-12	*Ovis*/*Capra*	Indeterminate	OxA-26086	6466	33	5510–5350	7460–7300
14 (N)	NV-3 (pit)	*Ovis aries*	–	Beta-131577	6590	40	5620–5460	7570–7410
15 (M)	NM-11	*Lathyrus* sp.	–	Beta-284146	7150	40	6080–5960	8030–7910
16 (M)	NM-11	*Pinus pinea*	–	Beta-284148	7490	40	6490–6210	8440–8160
17 (M)	NV-3	*Pinus pinea*	–	GifA-102010	7610	90	6650–6290	8600–8240
18 (E)	NV-4	*Capra pyrenaica*	–	Beta-156020	10040	40	9860–9340	11810–11290

They include the laboratory code, the taxon of the material analysed (including its identification by ZooMS when available, see Martins et al. 2015), its archaeological context, and calibrated dates at 1σ and 2σ obtained using the IntCal13 calibration curve (Reimer et al. 2013) in OxCal 4.2.3. (Bronk Ramsey and Lee 2013) [N=Neolithic; M=Mesolithic; E=Epipalaeolithic] albeit with its own chronological boundaries and a material culture with different traits as observed mainly in the ware (García Borja et al. 2014).

11.4 Zooarchaeological Data

The faunal collections recovered during the several excavations from 1979 to 1987 yielded a high number of animal remains. These come mainly from the campaigns directed by Francisco Jordá Cerdá, Manuel Pellicer and Pilar Acosta, and have been studied by several researchers. Boessneck and von den Driesch (1980) studied the first collection of mammals, avifauna and ictiofauna from the Mina and Torca chambers recovered by the Pellicer excavation of 1979. Morales and Martín (1995) analysed mammals from the Mina chamber from the campaigns of 1980, as well as those from the Torca chamber recovered in 1982. The ictiofauna from these latter campaigns was studied by Roselló et al. (1995), while the avifauna was analysed by Hernández (1995) and the molluscs by Serrano et al. (1997). The mammal materials from the campaigns of 1979, 1980, 1982 and 1983 carried out by Jordá have been studied by Pérez Ripoll (Aura Tortosa et al. 2005, 2010, 2011; Pérez Ripoll 1986) and Morales-Pérez (2015). The avifauna from the Mina chamber was classified by Eastham (1986), while the ictiofauna was studied by Rodrigo (Aura Tortosa et al. 2002; Rodrigo 1991) and the molluscs by Jordá Pardo (1986b). All these studies have provided abundant information on the composition of the Neolithic faunal assemblages at Nerja Cave, which gives an indirect idea as to the diet of its Neolithic inhabitants.

11.4.1 Faunal Composition of the Assemblages from the Mina and Torca Chambers

The mammalian faunal composition from the Neolithic phases of Nerja Cave includes mainly domestic taxa, between 95 and 70%, depending on the layer. The lower percentage of domestic taxa is found in the earliest Neolithic levels. This value is lower than that observed in more recent layers, most probably due to the intrusion, from the lower Mesolithic and Epipalaeolithic–Late Palaeolithic levels, of remains from wild Spanish ibex (*Capra pyrenaica*), red deer (*Cervus elaphus*) and rabbit (*Oryctolagus cuniculus*) (Table 11.3).

Concerning the domestic assemblage, cattle (*Bos taurus*) have a low numerical importance when all remains are taken into account, varying from 3 to 12%. Conversely, sheep (*Ovis aries*) and goat (*Capra hircus*) together represent the highest of the total number of domestic remains, ranging from 48 to 75%. Sheep alone contribute a higher proportion in all Early Neolithic levels (except in the assemblage from the excavation of 1980 at the Mina chamber, possibly due to the

Table 11.3 Mammals—NISP

	Torca (NT-79)			Torca (NT-82)			Mina (NM-79)		Mina (NM-80A+ NM-80B)			Mina (1979–1983)					Vestibulo (1982–1987)			
	AEN[a]	REN	MN	AEN	MEN	REN	AEN	MEN	AEN	MEN	REN	AEN	MEN	REN	MN	LN	ArEN	AEN	MEN	REN
Bos taurus	4	14	3	5	0	5	16	115	23	47	9	10	82	11	11	4	0	1	6	1
Ovis/Capra	33	78	28	153	9	19	127	630	183	261	88	139	785	302	143	38	0	142	340	78
Ovis aries	4	6	3	2	0	0	7	68	2	13	2	74	56	12	6	6	2	8	19	8
Capra hircus	2	7	2	0	1	0	12	36	6	7	7	7	13	6	8	5	0	0	3	1
Caprinae	0	0	0	0	0	0	0	0	0	0	0	19	4	0	0	0	0	0	0	0
Sus domesticus	14	22	8	0	0	0	37	112	0	0	0	46	90	35	27	10	2	7	26	4
Sus sp.	0	0	0	25	1	7	0	0	35	21	19	0	0	0	0	0	0	0	0	0
Canis famil.	4	6	0	0	0	9	1	3	1	4	2	1	4	1	3	0	0	0	1	1
Bos primigenius ?	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Capra pyrenaica	0	3	0	2	0	0	9	59	3	4	3	39	43	15	3	3	0	103	62	23
Cervus elaphus	0	4	3	0	1	1	2	5	5	3	2	15	26	8	17	18	0	2	0	0
Capreolus capreolus	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Sus scropha	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0
Monachus monachus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Lynx pardina	1	0	0	0	0	0	0	0	1	0	0	5	1	0	1	2	0	0	0	0
Felis silvstestris	3	0	0	0	0	0	1	4	0	0	0	0	2	0	0	0	0	0	1	0
Vulpes vulpes	2	0	0	0	0	0	1	0	0	0	0	8	2	0	1	0	0	0	0	0
Lepus sp.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Oryctolagus cuniculus	124	18	9	55	2	10	7	20	5	9	4	87	50	55	68	85	0	107	67	30
Total	*192*	*159*	*57*	*242*	*14*	*51*	*220*	*1058*	*264*	*369*	*136*	*451*	*1158*	*445*	*289*	*171*	*4*	*371*	*525*	*146*

Mina (NM-79) and Torca (NT-79) data collected from Boessneck and Drisch (1980). Mina (NM-80A + NM-80B) and Torca (NT-82) data collected from Morales and Martín (1995). Mina (1979–1983) and Vestibulo (1982–1987) is new data from this study

ArEN Archaic Early Neolithic, *AEN* Ancient Early Neolithic, *MEN* Middle Early Neolithic, *REN* Recent Early Neolithic, *MN* Middle Neolithic, *LN* Late Neolithic

[a] This level might have Epipalaeolithic intrusions

overall number of recovered remains being low), while goat is slightly more abundant than sheep in the Middle and Late Neolithic levels. Pigs (*Sus domesticus*) represent 6–19% of the total domestic remains found at all Neolithic levels, and thus are the next most important taxonomic group after ovicaprids.

Wild species found within the Neolithic levels of the site are Spanish ibex, red deer, lynx (*Lynx pardinus*), wildcat (*Felis silvestris*), fox (*Vulpes vulpes*) and rabbit. However, rabbit remains are scarce in the Neolithic layers compared to previous phases (Aura Tortosa et al. 2010; Morales-Pérez 2015). Two roe deer (*Capreolus capreolus*) bones have also been found, and another two could be identified as aurochs (*Bos primigenius*). The presence of seal is reported in the Boessneck and Driesch (1980) studies, but only one of the remains is actually documented. There is also a low presence of avifauna in the Neolithic levels (never more than 1% of the total; Table 11.4), the most abundant species being the wild rock dove (*Columba livia*).

The proportion of ictiofauna is low within the Neolithic sequence, but differs across excavations by different teams. Differences in sampling techniques and in recovery of remains might be the reason for these disparities. At the Mina chamber the presence of fish remains is very low in the Middle and Late Neolithic layers, shows a slight increase during the Early Neolithic, and reaches a peak within the Mesolithic-Epipalaeolithic levels (Fig. 11.2a). This same trend is observed at the Torca chamber (Table 11.5), for example in the case of the remains of *Sparidae* (Fig. 11.2b). Data from Jordá Cerdá's excavations indicate that the presence of molluscs at Nerja Cave shows a similar pattern to that of fish bones: abundant during the Mesolithic-Epipalaeolithic phases but showing a decline during the Neolithic. The increase in marine gastropods during the Neolithic is also observed, while bivalves are much more numerous during the Mesolithic-Neolithic "transition" and the Epipalaeolithic phases (Jordá Pardo 1986b; Serrano et al. 1997).

11.4.2 Discussion of the Results of the Faunal Analysis

There are two main issues that must be discussed regarding the faunal remains recovered from the Neolithic levels of Nerja Cave: the drastic shift between the faunal composition of the Mesolithic and the Neolithic levels, and the changes in anthropic activity regarding the processing of animal foods.

Data from Jordá Cerdá's excavations show that the majority of faunal remains found at the different levels of Nerja Cave are the result of human activity (Pérez Ripoll 2004). Domestic animals dominate the Neolithic faunal assemblage. Rabbit, which is very common in the Iberian Mediterranean region until the arrival of the Neolithic, is consistently found throughout the sequence (Aura Tortosa et al. 2005; Pérez Ripoll 2004). Although marine fauna such as mammals, birds, fish and molluscs are present, terrestrial animal remains clearly dominate the sequence suggesting that Neolithic human diet was based upon exploitation of the meat of domestic animals. The exploitation of the meat of wild taxa appears to have been

Table 11.4 Birds—NISP

	Torca (NT-79)			Torca (NT-82)	Mina (NM-80A + NM-80B)		Mina (1979–1983)				
	AEN[a]	MEN	REN	AEN	MEN	REN	AEN	MEN	REN	MN	LN
Calonectris diomedea	13	3	1	2	0	0	0	0	0	0	0
Sula bassana	7	1	1	3	1	0	0	0	0	0	0
Larus marinus	1	0	0	0	0	0	0	0	0	0	0
Larus argentatus	1	0	0	0	0	0	0	0	0	0	0
Aria aalge	0	0	0	0	0	0	0	1	0	0	0
Alca torda	0	0	0	0	0	1	0	0	0	0	0
Pinguinus impennis	1	1	0	0	0	0	0	0	0	0	0
Alectoris rufa	0	0	0	1	0	0	1	1	0	0	0
Coturnix coturnix	0	0	0	1	0	0	0	1	1	0	0
Columba livia	19	11	1	12	1	0	0	0	0	0	0
Fulica atra	1	0	0	0	0	0	0	0	0	0	0
Aythya ferina	1	0	0	0	0	0	0	0	0	0	0
Melanitta nigra	1	0	0	0	0	0	0	0	0	0	0
Anas crecca	0	0	0	0	0	0	0	0	0	1	0
Aquila chrysaetos	0	0	0	0	0	0	0	0	0	0	0
Aquila heliaca	1	0	0	0	0	0	0	0	0	0	0
Buteo buteo	0	0	0	0	1	0	0	0	0	0	0
Corvus corone	0	0	0	0	0	0	0	1	0	0	0
Hirundo rustica	0	0	0	2	0	0	0	0	0	0	0
Monticola solitaruis	0	0	0	0	0	0	0	3	0	0	0
Oenanthe lencura	0	0	0	0	0	0	0	1	0	0	0
Unidentified remains	0	0	0	0	0	0	6	6	3	2	28
Total	*46*	*16*	*3*	*21*	*3*	*1*	*7*	*14*	*4*	*3*	*28*

Torca (NT-79) data collected from Boessneck and Driesch (1980). Torca (NT-82) and Mina (NM-80A + NM-80B) data collected from Hernández (1995). Mina (1979–1983) data collected from Eastham (1986)

AEN Ancient Early Neolithic, *MEN* Middle Early Neolithic, *REN* Recent Early Neolithic, *MN* Middle Neolithic, *LN* Late Neolithic

[a] This level might have Epipalaeolithic intrusions

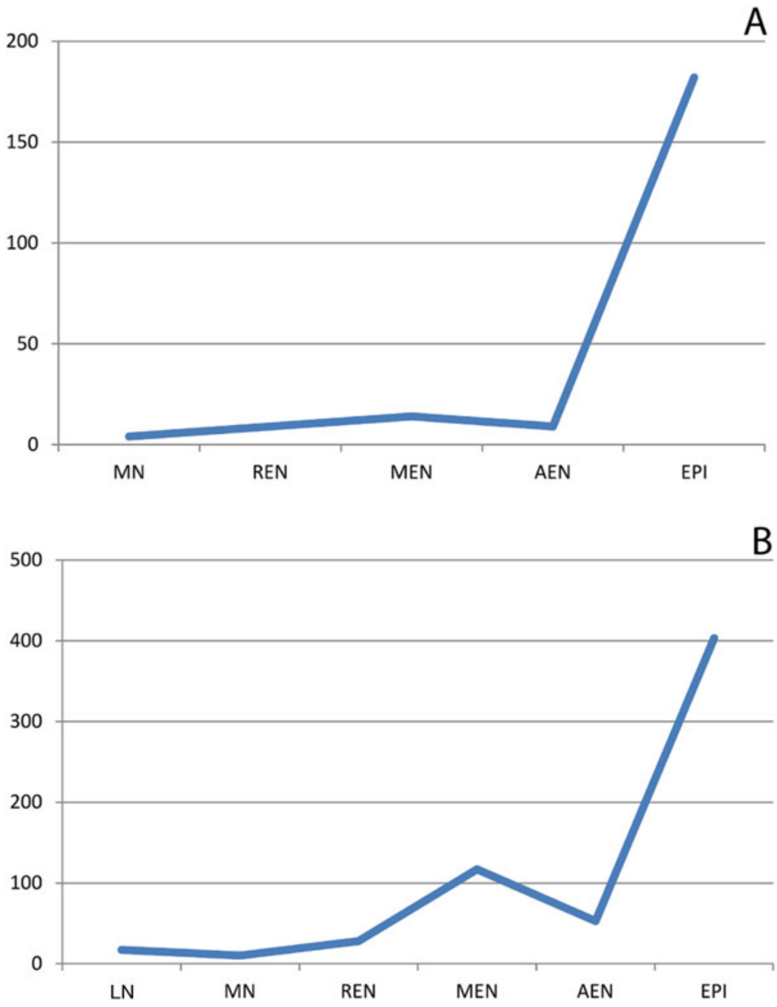

Fig. 11.2 (**a**) Mina chamber fish NISP (number of identified specimens) count; (**b**) Sparidae NISP from the Torca chamber. Data collected from Boessneck and Drisch (1980). *EPI* Epipalaeolithic, *AEN* Ancient Early Neolithic, *MEN* Middle Early Neolithic, *REN* Recent Early Neolithic, *MN* Middle Neolithic, *LN* Late Neolithic

rare. In comparison with the Epipalaeolithic, during the Neolithic the number of fish remains is very low. Similarly, the remains of both marine mammals (seal and dolphin) and sea urchins (Equinidae) are more frequently found in pre-Neolithic phases (Morales-Pérez 2015; Pérez Ripoll and Raga 1998; Villalba et al. 2007; Aura Tortosa et al. 2009).

The taphonomic processes observed reveal significant differences in animal processing between the Neolithic and the Mesolithic layers (Pérez Ripoll 1992). During the hunter-gatherer occupations, lithic marks on long bones are usually

Table 11.5 Fish—NISP

	Torca (NT-79)		Torca (NT-82)					Mina (NM-79)		Mina (NM-80A)				Mina (NM-80B)					Mina (1979–1983)				
	AEN[a]	MEN	AEN	MEN	REN	MN	LN	MEN	REN	AEN	MEN	REN	MN	AEN	MEN	REN	MN	LN	AEN	MEN	REN	MN	LN
Fish																							
Acipenser sturio	1	1	0	0	0	–	–	0	2	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Pollachius pollachius	0	0	0	0	0	–	–	0	3	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Dicentrarchus labraz/punctatus	0	0	0	0	0	–	–	0	2	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Epinephelus guaza	3	11	2	4	5	–	–	8	0	5	4	7	–	1	3	5	–	–	0	0	0	0	0
Sparidae	100	6	0	0	2	–	–	8	0	0	0	0	–	0	0	2	–	–	0	0	0	0	0
Pagrus pagrus	12	2	0	0	0	–	–	0	2	0	1	1	–	0	3	0	–	–	0	0	0	0	0
Pagrus auriga	0	0	0	0	1	–	–	0	0	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Pagellus erythrinus	50	2	1	0	1	–	–	1	2	2	0	0	–	0	0	0	–	–	0	0	0	0	0
Dentex dentex	0	0	0	0	1	–	–	0	0	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Dentex gibbosus	0	0	0	0	1	–	–	0	0	0	0	2	–	0	2	0	–	–	0	0	0	0	0
Dentex dentex/gibbosus	0	0	0	0	0	–	–	0	3	1	0	0	–	0	0	0	–	–	0	0	0	0	0
Sparus aurata	7	1	0	0	0	–	–	0	1	0	0	0	–	0	0	1	–	–	0	0	0	0	0
Diplodus sargus	1	0	0	0	0	–	–	0	0	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Trachurus mediterraneus	3	0	0	0	0	–	–	0	0	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Trachurus trachurus	0	0	0	0	0	–	–	0	0	1	0	0	–	0	0	0	–	–	0	0	0	0	0
Seriola dumerili	0	0	0	0	0	–	–	0	1	0	0	0	–	0	0	0	–	—	0	0	0	0	0
Scomber japonicus	0	0	0	0	0	–	–	0	3	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Thunnus thynnus	0	0	0	0	0	–	–	0	3	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Euthynnus alletteratus	0	0	0	0	0	–	–	0	1	0	0	0	–	0	0	0	–	–	0	0	0	0	0
Chelonlabrosus	0	0	0	0	0	–	–	0	0	0	1	0	–	0	0	0	–	–	0	0	0	0	0
Unidentified remains	0	0	0	0	0	–	–	0	0	0	0	0	–	0	0	0	–	–	55	117	28	10	14
Total	*177*	*23*	*3*	*4*	*11*	–	–	*17*	*23*	*9*	*6*	*10*	–	*1*	*8*	*8*	–	–	*55*	*117*	*28*	*10*	*14*
Molluscs																							
Gasteropoda	–	–	309	381	592	657	588	–	–	222	53	360	168	36	884	334	2078	6896	1838	2716	724	809	212
Bivalvia	–	–	74	27	22	26	22	–	–	8	4	29	10	4	17	12	74	141	630	491	33	37	16
Total	–	–	*383*	*408*	*614*	*683*	*610*	–	–	*230*	*57*	*389*	*178*	*40*	*901*	*346*	*2152*	*7037*	*2468*	*3207*	*757*	*846*	*228*

Torca (NT-79) data collected from Boessneck and Driesch (1980). Torca (NT-82), Mina (NM-80A) and Mina (NM-80B) data collected from Roselló et al. (1995). Mina (1979–1983) is new data from this study

AEN Ancient Early Neolithic, *MEN* Middle Early Neolithic, *REN* Recent Early Neolithic, *MN* Middle Neolithic, *LN* Late Neolithic

– Not studied

[a] This level might have Epipalaeolithic intrusions

longitudinal throughout the diaphysis, displaying the morphology of scratches or V-shapes. This pattern is associated with meat extraction, either for immediate consumption or for its preservation and storage. These extraction marks appear even in rabbit bones (Aura Tortosa et al. 2002; Pérez Ripoll 2004). Conversely, during the Neolithic the prevalent type of cut mark is that made transversally close to the articulation, which is associated to disarticulation. Longitudinal marks in the Neolithic only appear on large animal bones such as those of cattle, as well as on a few remains of red deer and Spanish ibex. The analysis of the typology and the position of the cut mark on the Neolithic bones suggests that the procedure for the extraction of meat from domestic goats, sheep and pigs was focused mainly on the head (maxillae, mandible ramus, hyoid bones) and axial units (ribs, vertebra spines).

This change in the patterns of meat extraction at the onset of the Neolithic could be explained by new culinary practices. Ceramic vessels allow the meat to be seasoned and cooked with cereals and legumes, without having to remove the flesh from all skeletal elements (with the exception of large-sized animals that would not fit inside these containers). As a result, the dominant mode of meat preparation in the Neolithic becomes the separation into portions of different parts of the animal, followed by cooking of the meat and bones together (which also allows exploitation of the marrow), rather than filleting.

Indeed, during the Mesolithic and Epipalaeolithic, some remains of cattle, red deer and Spanish ibex show percussion fractures. After the meat was extracted, attempts at extracting the bone marrow resulted in bones being systematically fractured: high primary fragmentation, yielding abundant diaphysis bone fragments with few preserved articulations and few complete long bones, can be observed. On the contrary, the use of bone marrow is completely different in the Neolithic, during which it is especially used for cooking of meat with cereals/legumes. After cooking, the remaining bone fragments, marrow and soft tissues are discarded and most likely used to feed the dogs, as attested by the fact that some complete long bones show evidence of canine consumption. Long bones, whole diaphyses and articulation parts are thus preserved by this new cooking technique (Table 11.6).

Table 11.6 Mina chamber: Percentage of long bone parts represented

	Neolithic	Late Palaeolithic–Epipalaeolithic
Entire bone	1.8	0
Whole proximal part of bone	2.7	0.8
Proximal fragment	3.8	11.5
Diaphysis cylinder	11.3	1.3
Diaphysis fragment	68.1	81.4
Whole distal part of bone	9.6	1.7
Distal fragment	2.5	3
	n = 1623	n = 625

Data from the Jordá excavations. Long bones considered are humerus, radius, tibia, femur, metacarpal, metatarsal.

Table 11.7 Mina chamber

	LN	MN	REN	MEN	AEN
Ovicaprids (NISP)	49	157	320	857	220
Dog bite-marks (NISP)	2	35	46	173	28
‰	4.1	22.2	14.3	20.1	12.7

Data from the Jordá excavations [AEN, Ancient Early Neolithic; MEN, Middle Early Neolithic; REN, Recent Early Neolithic; MN, Middle Neolitic; LN, Late Neolithic]

Fig. 11.3 Bone sample, representative of the state of preservation of the *Ovis*/*Capra* remains from the Neolithic. From left to right: neonate femur, young and adult femur diaphysis bitten by dogs, femur diaphysis with typical dog bite marks

A final observation on bone marks from the Neolithic layers is the fact that in Sala de la Mina there is a high incidence of canid bite marks. Bones with bite marks range from 4% during the Late Neolithic up to 22% in the Middle Neolithic (Table 11.7 and Fig. 11.3). On the contrary, no bones have been found displaying bite marks in the pre-Neolithic levels of NM. These changes might be showing differences between hunter-gatherer and farming communities regarding food refuse treatment.

11.5 Stable Isotope Analysis

11.5.1 Stable Isotopes and Dietary Reconstructions

The isotopic composition of food consumed by mammals is recorded, after a predictable isotope fractionation, in their body tissues (Schoeller 1999). Carbon and nitrogen stable isotope dietary studies are based on this principle (e.g. Lee-Thorp 2008; Makarewicz and Sealy 2015). Bone collagen is usually the preferred substrate for these analyses, not only as it is the only considerable source of nitrogen found in skeletal remains (Salazar-García et al. 2014a), but also due to the existence of accepted standard quality indicators which can be used to easily assess its isotopic integrity (De Niro 1985; Van Klinken 1999). However, when interpreting results it is always important to take into account the limitations of stable isotope ratios in bone collagen, which only reflect the average isotopic signals of the main dietary protein sources, consumed during several years prior to death (Hedges et al. 2007; Katzenberg 2012).

The consumption of C_3 and C_4 terrestrial resources is distinguishable by the $\delta^{13}C$ stable isotope ratio (Van der Merwe and Vogel 1978). Isotopic signals also help define the input in the diet of terrestrial and marine foods (Chisholm et al. 1982), although if freshwater or estuarine fish are involved the interpretation of $\delta^{13}C$ values becomes more complicated as observed for prehistoric times in the Western Mediterranean (Salazar-García et al. 2014b). The $\delta^{15}N$ stable isotope ratio increases by 3–5‰ up the food chain with each trophic level, and is usually used to indicate the position of an organism in the food chain (Minagawa and Wada 1984). Even if this quantification is less straightforward than previously thought (Hedges and Reynard 2007), based on the exact values of the nitrogen ratio it is theoretically possible to differentiate between individuals that consumed more animal resources from those who consumed very little animal proteins (Fahy et al. 2013). Furthermore, the fact that aquatic food chains tend to contain more trophic levels than terrestrial ones, and therefore show an increase in $\delta^{15}N$, helps to discriminate between the consumption of marine or C_4 terrestrial foods when samples are ^{13}C enriched (Schoeninger and De Niro 1984). As a complement to carbon and nitrogen stable isotope ratios, $\delta^{34}S$ isotope ratios can help to discriminate even further the consumption of aquatic resources or the proximity to the coast, but unfortunately require a much larger amount of extracted collagen for analysis (Nehlich 2015).

11.5.2 Methods

Methods outlined in Sealy et al. (2014) were followed to extract collagen for C and N isotope ratio analysis at the Light Stable Isotope Facility of the University of Cape Town (UCT) in Cape Town, South Africa. Whole-bone fragments weighing ca. 300 mg obtained from each of the specimens were demineralised in a 0.5 M HCl solution at 5 °C. They were then rinsed three times with deionised water until the pH became neutral, and gelatinised over 48 h at 70 °C before being filtered and ultrafiltered using 50–90 μm EZEE© filters and >30 kDa Amicon© ultrafilters, respectively. Finally, the purified solutions were frozen and lyophilised before being weighed into tin capsules and loaded onto the mass spectrometers.

The carbon and nitrogen isotope ratios in collagen were measured in duplicate using a Delta XP continuous-flow isotope ratio mass spectrometer interfaced with an elemental analyser, Flash EA 2112 (Thermo-Finnigan©, Bremen, Germany). All samples were analysed at the UCT light stable isotope laboratories. Stable carbon isotope ratios were expressed relative to the VPDB (Vienna PeeDee Belemnite) scale, and stable nitrogen isotope ratios were measured relative to the AIR scale (atmospheric N_2). All of these are expressed using the delta notation (δ) in parts per thousand (‰). Repeated analysis of internal and international standards determined an analytical error less than 0.1‰ (1σ) for $\delta^{13}C$ and $\delta^{15}N$.

11.5.3 Results

Three humans and twelve ovicaprid specimens were sampled for stable isotope analysis. Human remains from the Neolithic occupation phase were found between 1981 and 1984 in the NM chambers, specifically within contexts attributed to different stages of the Early and Middle Neolithic. The Neolithic occupation phases were directly dated using radiocarbon analyses performed on a variety of archaeological materials (Table 11.2). All human samples yielded sufficient collagen in the >30 kDa fraction for $\delta^{13}C$ and $\delta^{15}N$ analysis in duplicate. All of them met published collagen quality controls (i.e. C:N ratio between 2.9 and 3.6—De Niro 1985; Van Klinken 1999). All isotope ratio results from Nerja Cave are presented in Table 11.8 and illustrated in Fig. 11.4.

Analysing the carbon values, it can be seen that the ovicaprid $\delta^{13}C$ mean value is −18.2 ± 2.5 (1σ) ‰ and its minimum and maximum values are −20.1‰ and −11.4‰, respectively. Most of these herbivores group between −20.1‰ and −18.8‰, which is compatible with typical C_3 terrestrial ecosystems. However, some of them have such high $\delta^{13}C$ values as to place them in the range of a clear C_4 terrestrial environment. With regard to the nitrogen values, the ovicaprid mean $\delta^{15}N$ value is 5.1 ± 1.0 (1σ) ‰ and has minimum and maximum values of 2.8‰ and 6.6‰, respectively, thus defining the background for the herbivore trophic level at the site for the Early Neolithic and Middle Neolithic periods. Unfortunately, no aquatic resources could be analysed for this site from the Neolithic levels, and thus the aquatic background is lacking for this period at Nerja Cave.

If considering all humans ($n = 3$) from the Neolithic period as a whole at Nerja Cave, we see that they have $\delta^{13}C$ and $\delta^{15}N$ mean values of −19.1 ± 0.5 (1σ) ‰ (min: −19.4‰, max: −18.5‰) and 9.0 ± 0.2 (1σ) ‰ (min: 8.2‰, max: 10.3‰), respectively. These mean values suggest that at the population level, Neolithic diet was mainly based on terrestrial C_3 resources at Nerja Cave. The humans are clearly

Table 11.8 Carbon and nitrogen isotope ratio values, and collagen quality indicators (%C, %N, C:N, collagen yield), from all humans and animals studied from the Neolithic levels of Nerja Cave

S-UCT	Sample code	Period	Stage	Species	Bone	‰ Collagen	δ^{13}C (‰)	δ^{15}N (‰)	%C	%N	C:N
19993	NM F5/E5 Capa 7	Early Neolithic	Middle	Ovicaprid	Femur	1.0	**−20.1**	**6.0**	39,1	13,4	3,4
19994	NM F8 Capa 7	Early Neolithic	Middle	Ovicaprid	Vertebra	1.8	**−20.0**	**5.9**	40.8	14.5	3.3
19995	NM F3 Capa 8–9	Early Neolithic	Middle	Ovicaprid	Tibia	2.2	**−19.7**	**2.8**	43.0	15.3	3.3
19996	NM G4 Capa 8–9	Early Neolithic	Middle	Ovicaprid	Radius	0.7	**−19.8**	**3.9**	41.2	13.4	3.6
19997	NM E7 Capa 6	Early Neolithic	Middle	Ovicaprid	Metatarsus	1.5	**−11.4**	**5.6**	41.1	13.6	3.5
19998	NM E6 Capa 5	Early Neolithic	Recent	Ovicaprid	Rib	1.0	**−17.7**	**4.9**	40.2	14.6	3.2
19999	NM F7 Capa 5	Early Neolithic	Recent	Ovicaprid	Tibia	1.8	**−15.9**	**5.5**	43.0	15.2	3.3
20000	NM F6 Capa 4 n°255	Middle Neolithic	I	Ovicaprid	Rib	3.0	**−19.4**	**4.6**	43.9	15.3	3.3
20001	NM E6–7/F6–7/G7–8 Capa 4	Middle Neolithic	I	Ovicaprid	Tibia	0.8	**−18.8**	**5.4**	37.8	13.1	3.4
20002	NM F3 Capa 4	Middle Neolithic	I	Ovicaprid	Radius	0.7	**−19.4**	**4.4**	39.2	13.3	3.4
20003	NM F5/E5 Capa 4	Middle Neolithic	I	Ovicaprid	Cubitus	1.2	**−17.6**	**6.6**	42.4	15.2	3.3
20004	NM E6-F7 Capa 3	Middle Neolithic	II	Ovicaprid	Femur	2.4	**−18.8**	**5.7**	42.9	15.0	3.3
20005	NM F-8 Capa 7 n°72	Early Neolithic	Middle	Human	Rib	2.8	**−18.5**	**10.3**	41.3	14.5	3.3
20006	NM E6/F6 Capa 5	Early Neolithic	Recent	Human	Rib	3.9	**−19.4**	**8.2**	40.0	13.9	3.3
20007	NM G7–8/E6–7/F6–7 Capa 4	Middle Neolithic	I	Human	Rib	9.5	**−19.3**	**8.4**	44.1	15.7	3.3

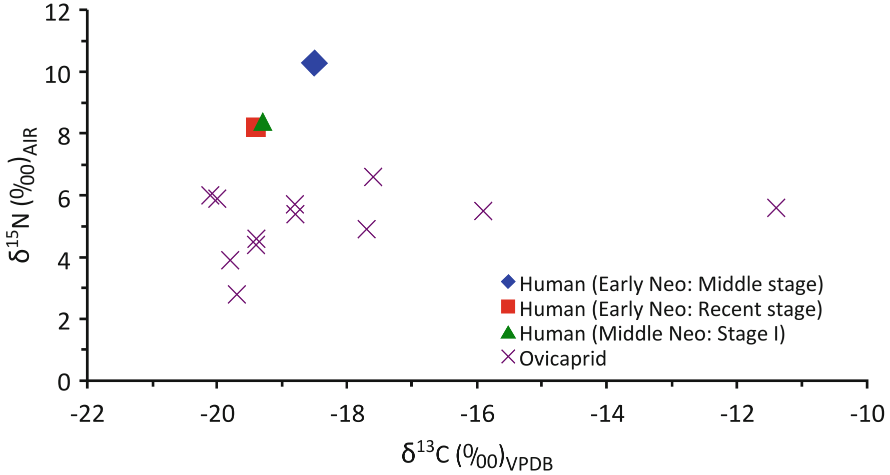

Fig. 11.4 Plot of human bone collagen $\delta^{13}C$ and $\delta^{15}N$ values from Neolithic Nerja Cave with those from faunal contemporary remains from the site

placed at a trophic level higher than the herbivores (more than 4‰ higher), suggesting that dietary protein input was based on the consumption of animal resources. However, if considering the levels from which each of the individuals analysed were sourced, there are some differences. The oldest of the individuals, associated to the middle stages of the Early Neolithic layers, yielded higher $\delta^{13}C$ and $\delta^{15}N$ values than the other two individuals, who come from a final stage of the Early Neolithic period and an early stage of the Middle Neolithic, respectively. The difference is of ca. 1‰ in $\delta^{13}C$ and ca. 2‰ in $\delta^{15}N$, and should therefore be considered. To some degree this variation between Neolithic stages could be due to differences in environment, husbandry or land use. However, it might also mean that the individuals from the middle stages of the Early Neolithic had marine protein input in their diet (enough to be reflected in the bone collagen values) while the later individuals did not. This last possibility is supported by the isotope values of the ovicaprids from the different periods and stages, since the $\delta^{15}N$ values are similar for all of them.

11.5.4 Discussion and Contextualisation of the Isotopic Data

It is very interesting to see how, overall, the Neolithic individuals from Nerja Cave show a similar dietary protein input throughout three different stages of the Neolithic: the middle stages of the Early Neolithic, the last stages of the Early Neolithic and the early stages of the Middle Neolithic. This shows that the diet for these farming communities was based on C_3 terrestrial resources and without major changes in time (ca. 1000 years span). The carbon and nitrogen stable isotope ratios are similar to those observed at other Neolithic-Chalcolithic sites in Mediterranean Iberia: Costamar (Salazar-García 2009), Cova dels Diablets (Salazar-García 2014), Coveta del Frare (García Borja et al. 2013), La Vital (Salazar-García 2011), Avenc dels Dos Forats and Cova de la Pastora (McClure et al. 2011). They are also similar to those observed for the Neolithic period around the Western Mediterranean as a whole (e.g. Le-Bras-Goude and Binder 2010; Le-Bras-Goude et al. 2012).

However, even if protein input came mainly from C_3 terrestrial resources, one of the individuals from Nerja Cave could have consumed enough marine resources such that their marine signature was detectable through isotope analysis of the bone collagen. This individual is the earliest individual from the three analysed, and was recovered in Layer 7 of NM, dating to the middle stages of the Early Neolithic. When plotting the data from Nerja Cave together with that available from Mesolithic and Neolithic Mediterranean Iberia, it could be argued that the earliest of Nerja's individuals falls within the same cluster of some Mesolithic individuals from the more northern region of Valencia (García-Guixé et al. 2006; Salazar-García et al. 2014b) and the coastal Middle Neolithic individuals showing isotopically detectable marine protein consumption (Salazar-García et al. 2016) (Fig. 11.5). This could be explained by regional differences or by the fact that the subsistence and economic strategies of the last hunter-gatherer groups and the first farmers might have been similar, at least in terms of their exploitation of aquatic resources.

Later on, with the arrival of new migration waves of farmers to the region, this low but detectable marine resource consumption is no longer observed at Nerja Cave. From the middle stages of the Early Neolithic onwards the coastline remained in the same place, and the productivity of the Mediterranean was presumably the same. Therefore, the explanation for the observed shift in marine resource consumption is not likely to be related to environmental factors, but rather

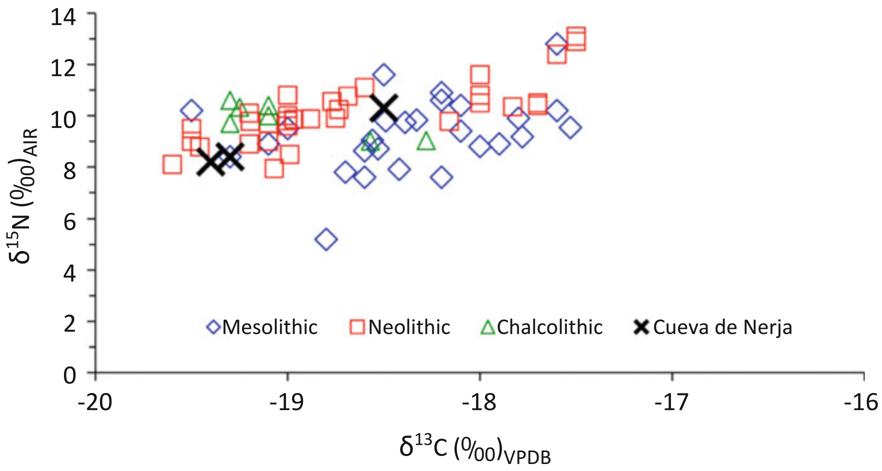

Fig. 11.5 Plot comparing human $\delta^{13}C$ and $\delta^{15}N$ values from Neolithic Nerja Cave with those from published Mesolithic and Neolithic human data from Mediterranean Iberia

to cultural-social-religious reasons. This has been argued before in order to explain the scarcity of isotopic evidence for marine resource consumption in the Neolithic elsewhere in Europe, even in regions where previously Mesolithic people consumed high amounts of aquatic resources (Richards et al. 2003), or in small islands (Richards et al. 2001).

What is new about the human data from Nerja Cave is the contrast it shows between the isotopic evidence for some marine resource consumption in the earlier Neolithic levels and its absence in later Neolithic stages. Could this mean that the last hunter-gatherers in the westernmost part of the Mediterranean Sea began to adopt the Neolithic lifestyle at the time of the arrival of the first colonial farmers from the East, but were eventually replaced by the newcomers? Or could it mean that the first farmers had a less refined Neolithic "package", one that required the consumption of "prohibited" foods in order not to starve? Of course, all of this is pure speculation, but nevertheless interesting; it shows the type of inferences that could be derived from isotopic data when combined with ancient DNA analysis and theoretical interpretive frameworks.

The direction of the colonial Neolithic waves and contacts are two other important issues upon which isotopic data can shed light. Oxygen and strontium isotope ratio analyse are commonly used to provide information on migration patterns (e.g. Bentley 2006; Pellegrini et al., 2016); however, carbon and nitrogen stable isotope ratio analysis can also be useful to this end. Their potential is associated with the existence of different isotopically detectable environments in the same broad region, allowing us to detect specimens originating from one environment within another. For the faunal specimens at Nerja Cave, a difference between southern European (mainly C_3) and northern African (mixed C_3-C_4) environments was detected (Sage et al. 1999), which could be related to trading networks. The presence of ovicaprid specimens with $\delta^{13}C$ values beyond that for a typical terrestrial C_3 environment (−17.7‰ during the Middle Neolithic, −17.6 and −15.9‰ during the recent stages of the Early Neolithic, −11.4‰ during middle stages of the Early Neolithic) is worthy of further investigation.

There are several potential explanations as to why these $\delta^{13}C$ values are higher than those of all other ovicaprids, for which the $\delta^{13}C$ values are lower than −18.5‰ and thus compatible with an environment dominated by C_3 plants. This pattern could be explained by the existence of a C_4 environment in southern Iberia (Mateu Andrés 1993) or by the use of different domestic animal feeding strategies, which would include C_4 plants or seagrass (Cooper and De Niro 1989). Another possible reason is that some of these ovicaprids lived in a C_4 environment and were subsequently transported to the C_3-dominated environment of southern Iberia as a result of the development of a trade network between both shores of the Western Mediterranean during the Neolithic. This would account for the fact that, while some ovicaprids have a full C_4 signature (e.g. lived in north Africa and died shortly after arriving in Iberia), others have a C_4–C_3 mixed signature (e.g. raised in north Africa and lived some time of their life in Iberia), and yet others display a full C_3 signature (e.g. raised and lived in Iberia). Although none of these possibilities could be ruled out, from an isotopic perspective, the one we consider most plausible is the existence of a commercial trade network of goods (including animals) connecting both shores of the Western Mediterranean. Future studies will be needed in the region to clarify this.

11.6 Final Thoughts

Nerja Cave, on the westernmost part of the Mediterranean, is a key site for the interpretation of patterns of Neolithic expansion in southern Europe. In particular, the study of faunal and human remains from this archaeological sequence, encompassing the periods of the last hunter-gatherers and the first farmers, sheds light on the dietary habits of these past societies. Interestingly, there are many fish, mollusc, crustacean and echinoderm remains within the sequence, but their quantity and composition vary over time. Nerja Cave is one of the few sites in the Mediterranean that yields such a variety of faunal remains over such a long temporal span that allow to assess marine resource exploitation both during different stages of the Neolithic and in comparison with that of hunter-gatherer communities.

The Neolithic economy was one of agriculture and farming, while other activities, such as hunting, fishing and shellfish gathering, played a secondary role. The zooarchaeological study clearly shows a low proportion of marine and small game remains and a high proportion of domesticates (such as sheep and goat) in the faunal assemblages within the Neolithic levels in comparison with earlier times. Animal processing techniques were also different between hunter-gatherers and the first farmers, with regard both to meat and marrow exploitation. The filleting of meat and bone marrow extraction are typical of pre-Neolithic contexts, while the cooking of anatomical elements together with cereals and legumes, as well as a different use of the marrow, are characteristics of Neolithic communities.

Integrating the zooarchaeological analysis with the isotopic analysis on human remains allows us to obtain direct information on their actual diet over time. Isotopic analysis of the bone collagen from the Neolithic individuals at Nerja Cave shows that, even if their diet was based on terrestrial C_3 resources throughout the Neolithic, an input from marine proteins was isotopically detectable on one individual from the earlier stages of the Neolithic only. This might suggest that the first farmers interacted significantly with the last hunter-gatherers and might have adopted or shared some of their economic practices (i.e. marine exploitation). However, later migrations at the end of the Neolithic might have introduced a more rigidly terrestrial-based diet, perhaps associated with some cultural-social practices which forbade the exploitation of foods coming from the sea.

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Part V
Human Dispersal Mechanisms and Cultural Transmission

Chapter 12
The Mesolithic-Neolithic Transition in Europe: A Perspective from Ancient Human DNA

E. Fernández-Domínguez and Luke Reynolds

12.1 An Archaeological Framework for the Interpretation of the Genetic Data

The mechanisms involved in the transition from a foraging to a farming lifestyle in Europe have been extensively discussed in archaeology during most of the last century. Traditionally, the debate has taken the form of a dichotomy between two opposing models which, in turn, have different implications on the discussion about the origins of the European genetic pool. On one hand, the *cultural diffusion model (CDM)* explains the introduction of agriculture through a process of technological transmission from the first Near Eastern farmers and adoption of subsistence strategies by the indigenous European hunter-gatherers. This model assumes none or negligible genetic admixture between both groups and therefore implies a predominant hunter-gatherer genetic ancestry in Europe (Dennell 1983; Barker 1985; Tilley 1994; Thomas 1988, 1996; Whittle 1996). On the other hand, the *Demic Diffusion Model (DDM)* postulates that agricultural practices fuelled a population increase amongst the first Near Eastern farmers, forcing them to colonise new territories in Europe. This process would have ultimately led to the genetic

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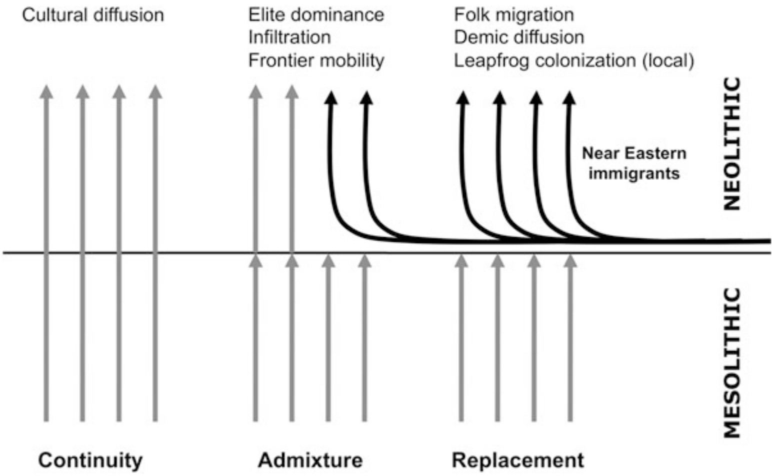

Fig. 12.1 Genetic implications of models of Neolithic diffusion

replacement of the hunter-gatherer genetic legacy due to the demographic superiority of the Neolithic incomers (Ammerman and Cavalli-Sforza 1984). Between both extremes, the integrationist models advocate for certain degree of admixture between local hunter-gatherers and Neolithic immigrants through different mechanisms like elite dominance (Renfrew 1987), infiltration (Neustupny 1982), leapfrog colonisation (Arnaud 1982; Zilhão 1993) or frontier mobility (Zvelebil 1996; Zvelebil and Lillie 2000). These scenarios translate into different grades of gene mixing between local hunter-gatherer populations and exogenous farmers (Zvelebil 2001) (Fig. 12.1).

The biological mechanisms involved in this cultural shift are difficult to determine just by examining the archaeological evidence alone. In this framework, ancient DNA analyses of human remains have the potential to distinguish migration processes from acculturation mechanisms provided that the genetic background of Near Eastern farmers and European hunter-gatherers is different enough to be distinguishable with current analytical methods. It is also important to note that the spread of farming was neither a linear nor a homogeneous process. The Neolithic way of life expanded following different routes, in different waves and through a combination of different mechanisms, which might have also occurred simultaneously in certain places (Guilaine 2000; Price 2000). All these aspects should be considered and properly addressed when building an interpretative framework for the increasing body of ancient DNA data from the Mesolithic-Neolithic transition period.

12.2 Genetic Signatures of the Neolithic Spread in the Modern Gene Pool?

Studies based on the genetic characterisation of modern human populations assume that events of demographic growth, population movement and admixture leave an imprint in the genetic make up of the populations, which can be detected using appropriate statistic tools (Jobling et al. 2004). Under this premise, different works have attempted to detect signatures of prehistoric and historic population events on the modern genetic pool and to quantify their relative contribution.

Three types of genetic markers have been traditionally used with this purpose: the mitochondrial DNA (mtDNA), the male specific region of the Y chromosome (MSY) and specific regions within non-sexual chromosomes (autosomes), either gene variants (alleles) or Single Nucleotide Polymorphisms (SNPs) (mutations, insertions or deletions). Both mtDNA and MSY are transmitted unchanged through the maternal or the paternal line for generations, thus allowing every variant (haplotype) to be traced back in time. On the contrary, autosomal markers have a mixed pattern of inheritance, where each progenitor contributes one chromosomal version of the same gene or SNP (Fig. 12.2). Traditionally, haploid genetic markers (mitochondrial DNA and Y chromosome) have been used to account for continuities/discontinuities between cultures, as their uniparental mechanisms of transmission allow direct comparisons to be performed between periods. Amongst these, mitochondrial DNA has been more extensively used in ancient DNA because of its proportional abundance in the cell when compared to nuclear DNA (1 to 1,000 ratio), a characteristic that facilitates its retrieval in degraded samples using conventional PCR (Giles et al. 1980).

The first attempt to address the question of the genetic contribution associated to the spread of agriculture corresponds to the analyses conducted by the team of Cavalli-Sforza during the 1970s–1990s. The variability of a set of genes, the so-called "classic genetic markers" (HLA, erythrocyte enzymes and plasma proteins), was studied in different European populations. Frequencies of the different alleles were summarised using Principal Component Analysis (PCA). The spatial

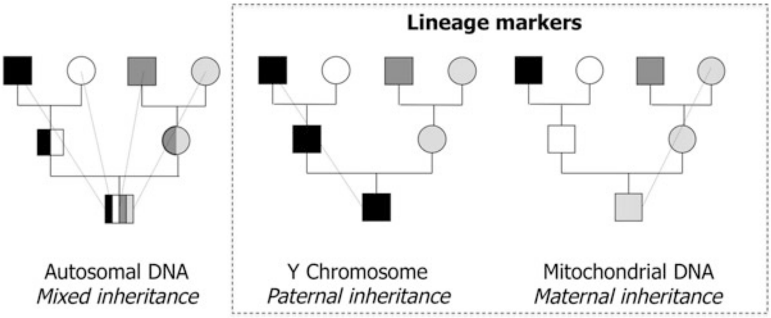

Fig. 12.2 Inheritance of genetic markers

interpolation of the two first principal components showed a SW-NE cline, which was interpreted as a signal of the genetic signature left by the expansion of the first Near Eastern farmers into Europe (Cavalli-Sforza et al. 1993, 1994; Menozzi et al. 1978). This result was used as overwhelming evidence to support the DDM, even though the variability explained by both variables accounted for only 27% of the total. The frequency distribution of Y chromosome polymorphisms in Europe produced comparable results (Semino et al. 1996, 2000), with Y chromosome haplogroups F*, E3b, G and J2 (representing 22% of extant lineages) being proposed as the main contributors to the Neolithic spread (Rosser et al. 2000). Genetic simulation analyses with the same data also gave support to the DDM model while providing higher estimations about the Neolithic genetic input, in some cases as high as 50–60% (Chikhi et al. 2002; Currat and Excoffier 2005).

The analysis of the mitochondrial DNA variability of extant European and Near Eastern populations reopened the discussion in the mid-late 1990s and early 2000s, when, in contrast with previous evidence, different studies proposed a predominant role of Late Upper Palaeolithic Post Glacial Expansions in the shaping of the European gene pool and a minor genetic contribution associated to the diffusion of the Neolithic (Richards et al. 1996, 2000). According to these studies, the vast majority of mtDNA haplogroups would have arrived in Europe during the Palaeolithic (H, HV*, U, U1, U2 and U4). The Neolithic expansion would have brought representatives of haplogroups J, T1 and U3 together with some clusters of H and W (Richards et al. 2000). Additional phylogeographic analyses identified other haplogroups involved in the recolonisation of Europe from particular southern refugia after the Last Glacial Maximum: haplogroups V, H1, H3, H5, U5b3 in the Cantabrian fringe (Achilli et al. 2004; Pereira et al. 2005; Tambets et al. 2004; Torroni et al. 1998, 2001), sub-group U5b3 in the Italian Peninsula (Pala et al. 2009) and clusters U4 and U5a in the Eastern European Plain (Malyarchuk et al. 2008, 2010). In recent years, the increase in phylogenetic resolution achieved by the recovery of full mitogenomes coupled with the integration of ancient DNA data has provided a more holistic approach to the archaeogenetics of Europe (Pala et al. 2012; Soares et al. 2010), ultimately shifting again the balance in favour of the “Neolithic wave of advance” model (Fu et al. 2012).

New genetic data from both modern and ancient populations has depicted a more complex picture, questioning the ability of modern population genetic analyses to detect prehistoric demographic events. Genome-wide ancient DNA analyses, for example, have highlighted the predominant role of post-Neolithic events in the shaping of the genomic structure of European populations, specifically those migrations related to the expansion of Bronze Age cultures (Allentoft et al. 2015; Haak et al. 2015). A similar pattern has been inferred from a deep sequencing of the male specific region of the Y chromosome (Batini et al. 2015). In the same line, genome-wide SNP data from Modern Europeans suggests that admixture events that took place during historical periods, and not major prehistoric migratory processes, are responsible of the current genetic variability of European populations (Busby et al. 2015). Taking all these into consideration, it seems that the only way to overcome the limitations imposed by the analysis of current genetic variability is the direct genetic analyses of the protagonist populations. This approach is not exempt of challenges and will come with its own limitations, as we will discuss in the following section.

12.3 Ancient DNA and the Neolithic Spread Debate

The potential of ancient DNA to provide an accurate estimate of the genetic diversity of a particular period, culture and place is unquestionable. Its application to the study of the Mesolithic-Neolithic transition can illuminate the biological processes of interaction between hunter-gatherers and Neolithic farmers. However, moving from raw data to the formulation of models of interaction and admixture is far from straightforward.

One of the main limitations is the chronological and geographical representativeness of the available data. The lack of inhumations from the period and region of interest, the restrictions in gaining access to the samples and/or the state of molecular preservation of the human remains forces the clustering of samples from different places and periods lacking of cultural and population entity. This ultimately results in an overall loss of resolution and an underestimation of the underlying population genetic substructure. Overcoming these issues is not an easy task, but maybe the first step should be recognising the limitations of this approach and being able to acknowledge that in order to accurately reconstruct human social and demographic events from the past, different factors beyond genetics should be taken into account.

Like modern population genetics, the study of ancient human DNA has undergone transitions concordant with innovations in genotyping technologies. Early debate was centred almost exclusively on the analysis of mitochondrial DNA, and the main bulk of data from Mesolithic and Neolithic human remains correspond to this genetic marker. The use of mtDNA to the study the transition to farming has been extensively criticised due to its inability to show the whole picture. Different roles for males and females in terms of patters of mobility, social organisation and marriage might have caused a differential distribution for the female and male lineages associated to the Neolithic transition, therefore the analysis of a single locus may not reflect the true story of the population (Bentley et al. 2012; Rasteiro et al. 2012; Rasteiro and Chikhi 2013).

The knowledge of the paternal equivalent to the mtDNA—the Y chromosome—seems then of the uttermost importance for understanding both perspectives of the Neolithic transition process. Unfortunately, access to this and other chromosomal markers has been seriously limited by the lack of protocols sensitive enough to overcome its low DNA concentration in ancient remains. The development of Next Generation Sequencing techniques (NGS) (Margulies et al. 2005) has provided the ancient DNA field with a new way to approach and explore the genomic variation and to overcome some of the main drawbacks of classical PCR approaches. Even though to date the Neolithic Y chromosome database is still scarce, the body of genomic and therefore Y chromosome data is growing and it is expected that once methods of Y chromosome capture are further developed it will increase even more (Lippold et al. 2014).

At present, within the post-genomic era, genome-wide typing of million of polymorphisms for many individuals is possible with NGS, facilitating a dramatic increase in the quantity of genetic data available for addressing questions of European prehistory and enhancing our ability to make inferences about past populations. The application of this approach to the transition to farming is fairly recent, but during the five years that have passed since the first draft genome of one Mesolithic skeleton was published, we have witnessed the publication of more than 500 ancient human genomes, including those from Early farmers across Europe.

In the following paragraphs the contribution of human ancient DNA to the Mesolithic-Neolithic debate will be detailed and discussed in the light of the available archaeological background.

12.4 The Original Neolithic Gene Pool: DNA from the Core and Interim Areas of Neolithisation

The core areas in the Near East—the Levant, northern Syria, Iraq, south-eastern Turkey and Central Anatolia—represent the original regions of development of agriculture and husbandry practices. From these, the Neolithic expanded into Europe following different mechanisms and pathways. Consequently, in the context of the transition to farming in Europe, the knowledge of the genetic makeup of the first farmers is paramount for the correct distinction between external (Near Eastern Neolithic) genetic input and local (hunter-gatherer) genetic background.

The lack of representative genetic data from the original Near Eastern Neolithic population has limited the scope of the conclusions drawn from the palaeogenetic analysis of Early Neolithic European remains, and until very recently modern Near Eastern populations have been used as a comparative data frame for ancient DNA analysis.

So far, ancient DNA data has been obtained out of 41 individuals from pre-pottery Neolithic sites (mainly PPNB but also PPNC) in the Fertile Crescent corresponding to the three core regions of Neolithic development: the Levant (available data from Syria, Jordan and Israel), the Zagros mountains in Western Iran and the Central Anatolian Plain (Broushaki et al. 2016; Fernández et al. 2014; Kılınç et al. 2016 and Lazaridis et al. 2016). The markers studied vary between regions and sites. Only partial mitochondrial profiles from 15 individuals are available from the Northern Levantine sites (Tell Halula in the Middle Euphrates Valley and Tell Ramad in the Oasis of Damascus, ca. 8000BCE) (Fernández et al. 2014). From the Southern Levant region, genomic data could be retrieved out of 12 skeletons from ´Ain Ghazal in Jordan (8300-6700BCE) and 1 from Tell Motza in Israel (7300-6750BCE) together with mitochondrial and Y chromosome haplogroup data in a subset of them (Lazaridis et al. 2016). Genome-wide SNP information is also available from 9 skeletons from the Zagros mountains in Western Iran: 5 from Tepe Ganj Dareh (8,000-7,000 calBCE), 3 from Tepe Abdul Hosein, (8200-7750 calBCE) and 1 from Wezmeh Cave (7455-7082 calBCE) (Broushaki et al. 2016; Lazaridis et al. 2016;). Mitochondrial and Y chromosome data could also be obtained from six and three of these skeletons respectively. Finally, the PPNB site of Bonkuclu Höyuk in Central Anatolia (8300-7950 calBCE) produced genome sequence data for 4 additional individuals (Kılınç et al. 2016). With the exception of Fernández et al. 2014, mitochondrial and Y chromosome haplotypes were not presented in the original publications, which restricts the scope of the interpretation of these data to the distribution of the haplogroup frequencies. The PPNB is one of the earliest manifestations of the Neolithic in the Fertile Crescent, and it is during this period that animal husbandry first appears. Full-scale agricultural practices are documented and an increase in population density from previous periods can be inferred from the size of the settlements and the number of excavated human remains (Guerrero et al. 2008).

Genome-wide analyses showed a striking regional genetic differentiation between the first Near Eastern farmers from the Southern Levant, the Zagros and Anatolia (Brushaki et al. 2016; Lazaridis et al. 2016). These studies also support genetic continuity within the different regions between farmers and local hunter-gatherer populations, represented by a sample of 6 Natufians from Raqefet Cave (Israel, ca. 12000-9000 BCE) in the Southern Levant and 1 allegedly Epipalaeolithic sample from Hotu Cave in Northern Iran that yielded however a radiocarbon date of 6218-6034 calBCE (see Supplementary Information 1 in Lazaridis et al. 2016). The observed levels of genetic substructuring within the Fertile Crescent can be interpreted as evidence of an independent adoption of agriculture from the predecesor hunter-gatherer populations in the different centres of Neolithic development, which was fostered by cultural exchanges rather than by genetic flow.

The PPNB farmers from Central Anatolia are genetically closer to the Early European farmers than the samples from the other two Neolithic core regions (Figure 2a Kılınç et al. 2016 and Figure 1b Lazaridis et al. 2016), which has been used as an argument to support an Anatolian origin for the earliest manifestations of the Neolithic in Europe. However, this does not exclude migrations from other areas to have occurred at different times. In fact, gene flow from the Levant into Europe during the PPNB has been proposed as a suitable explanation for the assymetry observed in the $f4$ statistics between the Natufians and the PPNB Southern Levant to the ancient West Eurasian population (Lazaridis et al. 2016, Supplementary Information 7).

Data from Pottery Neolithic sites in the Marmara region of Anatolia—Menteşe Höyük, 6400–5600 calBCE and Barcın Höyük 6600–6000 calBCE—are also available (Mathieson et al. 2015). These sites are within the secondary areas of Neolithisation or “interim zone”, where the Neolithic package appears at the beginning of the 7th millennium (Özdogan 2008).

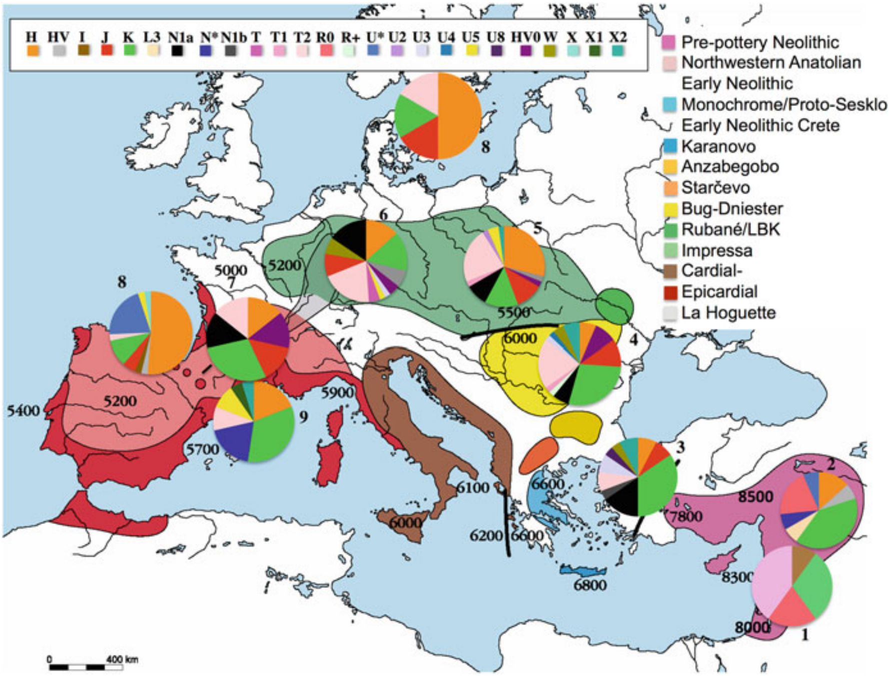

Fig. 12.3 Mitochondrial haplogroup frequencies in Early Neolithic cultures. Map after Guilaine 2000. *1*, Pre-pottery Neolithic B and C from Jordan and Israel (Lazaridis et al. 2016); *2*, Pre-pottery Neolithic B from Syria (Fernández et al. 2014); *3*, Anatolian Pottery Neolithic (Mathieson et al. 2015); *4*, Starčevo-Cris-Körös (Gamba et al. 2014; Hervella et al. 2015; Szécsényi-Nagy et al. 2015); *5*, Transdanubian LBK (Gamba et al. 2014; Szécsényi-Nagy et al. 2015); *6*, German LBK (Brandt et al. 2013; Brotherton et al. 2013; Haak et al. 2015, 2010); *7*, Cardial/Epicardial Aragón (Gamba et al. 2012; Haak et al. 2015); *8*, Epicardial Cantabria (Hervella et al. 2012); *9*, Cardial/Epicardial Catalonia and Valencia (Gamba et al. 2012; Lacan et al. 2011; Olalde et al. 2015); *10*, TRB Scandinavia (Mälmstrom et al. 2009; Skoglund et al. 2012, 2014)

Genome-wide data analyses performed on these samples showed that their genetic diversity falls in the vicinity of Early European Neolithic populations from Hungary (1 Körös, 1 Starčevo, 5 Alföld Linear Pottery, 2 Transdanubian LBK and 1 member of the Lengyel culture), Germany (15 LBK) and North-Eastern Spain (5 Epicardial) (Gamba et al. 2014; Haak et al. 2015; Mathieson et al. 2015, Fig. 1b). The mitochondrial DNA composition of these populations also mirrors the Starčevo-Çris-Körös, Transdanubian and German LBK data, displaying a set of common haplogroups: K, N1a, T2, X2, H and J (Fig. 12.3). In addition, the Anatolian samples also show a high frequency of Y chromosome haplogroup G2a (48%), characteristic of Early European farmer samples (Fig. 12.4). However, unlike the similarities observed at genome-wide level, the mitochondrial DNA of the Anatolian farmers—excluding a high frequency of haplogroup K and basal levels of haplogroup N1a—is different from the Iberian Cardial/Epicardial

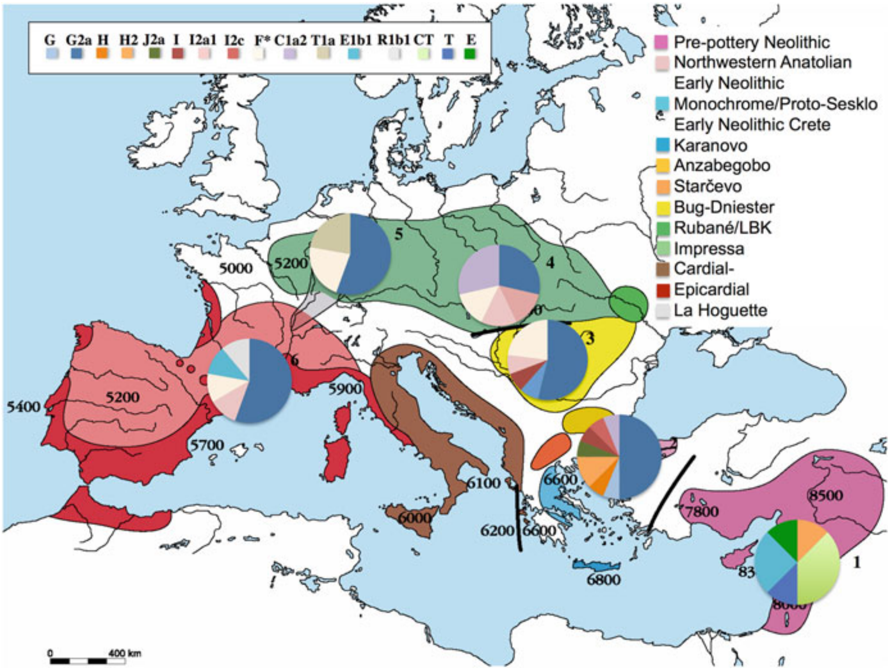

Fig. 12.4 Y chromosome haplogroup frequencies in Early Neolithic cultures. Map after Guilaine 2000. *1,* Pre-pottery Neolithic B and C from Jordan and Israel (Lazaridis et al. 2016); *2*, Anatolian Neolithic (Mathieson et al. 2015); *3*, Starčevo (Szécsényi-Nagy et al. 2015; Lazaridis et al. 2014); *4*, Transdanubian LBK (Gamba et al. 2014; Szécsényi-Nagy et al. 2015); *5*, German LBK (Haak et al. 2010, 2015); *6*, Cardial/Epicardial Aragón (Haak et al. 2015; Lacan et al. 2011)

populations (Gamba et al. 2012; Haak et al. 2015; Hervella et al. 2015; Lacan et al. 2011). Only one archaeological site was included in the whole genome comparisons (Cueva de Els Trocs in Aragón, Spain), while mitochondrial DNA data are available from five different archaeological sites and three different locations within North-Eastern Spain (Can Sadurní, Sant Pau del Camp and Cova de l'Avellaner from Catalonia; Chaves, Els Trocs from Aragón and Paternanbidea and Los Cascajos from Navarre). Taking that into account, it is possible that the differences observed between genomic and mitochondrial data could be due to the existence of genetic structure within the Early Neolithic Iberian populations, resulting from regional differences, genetic drift, endogamic practices or differential contacts with other Neolithic groups.

The observed genetic similarities between the Western Anatolian Pottery Neolithic and the Early European Neolithic cultural groups do not necessarily imply that the latter directly descend from the former. The northern territories of the Marmara region were densely occupied by hunter-gatherers until the arrival of the precursors of the Fikirtepe group, and it has been suggested that both groups merged and the migration did not progress beyond the Istanbul area (Özdogan

2011). Even though some migration occurred along the southern coasts of Marmara into Thrace, this does not seem to have been a very dense movement according to the distribution of archaeological sites. The main migration reaching Greece and the Balkans took place at 6100–5900 BCE from Central Anatolia and brought a different pottery horizon, the red-slipped pottery, precursor of the different stylistic pottery complexes in the Balkans (Özdogan 2014).

In order to resolve the apparent contradiction between the genetic and archaeological data, alternative scenarios of expansion should be proposed and tested (Mathieson et al. 2015). Aside from the Early Neolithic communities of the Balkans being the successors of the Western Anatolian Neolithics, the genetic similarities observed between both groups could be also explained (1) through migration of people from a different region in Anatolia with a similar genetic makeup or (2) as a result of back-migration and contact episodes between Thrace and Anatolia during this period. The similarities observed at both genome-wide and mitochondrial DNA levels between PPNB Central Anatolians from Boncuklu and the Pottery Neolithic farmers from Barcin, in principle give support to the first scenario, but the mechanisms of interaction among these first farming communities cannot be inferred from the ancient DNA data alone (Kılınç et al. 2016). The observed increase in diversity from the Pre-pottery to the Pottery Neolithic in Central Anatolia may be indicative of gene flow from other regions, thus adding an extra layer of complexity in the search for the genetic source of the European Neolithic gene pool.

Furthermore, the degree of interaction of the Anatolian and Southeastern European Early Neolithic populations with the local Anatolian Epipaleolithic and the European Mesolithic communities, respectively, is also unknown. Even though the tests of admixture conducted over whole genomic data have suggested basal levels of hunter-gatherer ancestry of 7–11% in Early European populations, it is important to note that Western hunter-gatherers were used as model populations for the estimation of ancestry (Mathieson et al. 2015). In the light of new mitochondrial data from the Mesolithic site of Theopetra in Thessaly showing mitochondrial types characteristic of Early European farmers, the role of mechanisms of acculturation in the early stages of Neolithic diffusion should not be disregarded (Hofmanová et al. 2016). In the same publication, genome-wide data from Early and Late Neolithic Greek individuals showing striking similarities with two additional individuals from Barcın is also presented. The biological processes that gave rise to these similarities are again difficult to ascertain in the absence of Mesolithic genomic data from the region. In this situation, both a common-similar Mesolithic genetic background for Anatolia and Greece and the Greek samples being direct descendants of Neolithic Anatolians as a result of migration are equally plausible.

In terms of mitochondrial DNA composition, both Levantine sampled regions share haplogroups R0 and K (Fernández et al. 2014; Lazaridis et al. 2016). The most notable difference with the Pre-pottery/Pottery Anatolian Neolithic is the absence of the mitochondrial haplogroup N1a in the Levant. As it will be discussed later, this haplogroup is ubiquitous in Southeastern and Central Europe during the Early Neolithic, and even before the first Anatolian Neolithic data was published, it had been proposed as a genetic marker of the Neolithic expansion (Haak et al. 2010).

In this regard, the data presented in Kılınç et al. (2016) and Mathieson et al. (2015) provides the piece of evidence that ultimately allows us to link this mitochondrial type to the Near Eastern farming communities.

The Iberian Cardial/Epicardial culture from Catalonia displays a parallel haplogroup composition to the Syrian PPNB sample. The presence of rare haplogroup N* in both genetic backgrounds confirms the existence of population connections between both edges of the Neolithic distribution previously suggested by archaeological data (Gamba et al. 2012). A European Palaeolithic origin of haplogroup N* has been proposed based on its presence in Mesolithic Portuguese shellmiddens and in Paglicci-12, an Italian Cro-Magnon specimen (Caramelli et al. 2003; Chandler 2003), but in our opinion this claim is not sustained by the available data (Brandt et al. 2014). The first dataset is unpublished and not publically accessible, and consequently has not undergone a process of peer review to assess either the quality of the data or their adherence to current criteria of authenticity. Moreover, even though Paglici-12 was tentatively classified as belonging to macrohaplogroup N due to the combination of coding region SNPs 00073G, 10873C, 10238T, 10398A, 10400C and mtDNA-HVRI (16223T), mutations 10873C, 10398A and 10400C identify it as a member of the basal haplogroup L3 according to the most updated mtDNA phylogeny (Phylotree build 16. Kloss-Brandstätter et al. 2011; van Oven and Kayser 2009).

The projection of the PPNB ancient mtDNA diversity over the modern genetic pool of Near Eastern and Southwestern European populations showed clear genetic affinities with Cyprus, and it was suggested then that these communities may have expanded into Europe following a sea route through Cyprus and the Aegean islands. Maritime routes of expansion are thought to have played an important role in Early Neolithic dispersals, but again their significance is difficult to assess with genetic data alone. In the case of Cyprus and the islands of the Aegean, the maritime dispersal hypothesis finds support in archaeological evidence (Bocquet-Appel et al. 2009; Broodbank and Strasser 1991; Peltenburg et al. 2000; Perlès 2005; Vigne et al. 2012), but for it to be properly confirmed by palaeogenetic evidence, specimens from Cyprus, Crete and the Aegean should be studied and compared.

The differences between modern and Neolithic populations from the Near East observed at mitochondrial and genome-wide levels indicate that a shift in the genetic background of these populations occurred after the Neolithic (Mathieson et al. 2015). This is not surprising, as ancient DNA studies had already pinpointed the crucial role of post-Neolithic migrations in re-shaping the genetic pool of modern Europeans and in blurring the genetic signature associated to the spread of the Neolithic in Europe (Brandt et al. 2013; Haak et al. 2015), so it seems sensible to think that the same scenario might have occurred in the Near East. These findings question the use of modern Near Eastern populations as a proxy for the original makeup of Neolithic populations.

Even though the available genetic data from Near Eastern Neolithic skeletons seems incredibly promising, the picture is still incomplete and key questions regarding the emergence, population structure and dynamics of the first farming communities still remain unanswered. More Near Eastern Neolithic data is needed in order to reconstruct the level of genetic differentiation within the core and the interim areas of Neolithic development dispersal into Europe. An integration of genetic data and other lines of evidence, including archaeology, would also be desirable in order to define and refine the levels of interaction within and beyond the Near Eastern interaction sphere and to propose and test different routes of expansion of the Neolithic out of the Fertile Crescent into Europe.

12.5 From the Near East into Europe: Ancient DNA from the Aegean and the Balkans

The earliest farmers in Europe appeared in the Aegean at the beginning of the 7th millennium BCE to quickly expand into the south of the Balkan Peninsula at around 6600–5800 BCE (Chapman and Dolukhanov 1993; Demoule and Perlès 1993). This process has been explained as a result of direct Neolithic colonisation due to the absence of a Mesolithic occupation in the area, but the presence of preceramic phases in some Aegean sites has cast doubt as to whether independent adoption might have been occurred instead (Tringham 2000).

A distinction based on regional characteristics and geopolitical location has been made amongst the first Balkan Neolithic cultures: the Cris, Körös and Starčevo cultural complex in Romania, Hungary and Serbia. Even though a great degree of stylistic uniformity is recognised at different levels (pottery, settlement, architecture, etc.), whether the observed differences are a result of a cultural regionalisation or the manifestation of different population backgrounds is still being debated (Tringham 2000).

There are many ways in which ancient human DNA can assist and inform these issues if the right periods and regions are studied. The palaeogenetic data corresponding to the first European manifestations of the Neolithic is scarce, as well as geographically and chronologically scattered. As discussed before, preliminary results are available from 2 Mesolithic and 1 Aegean Early Neolithic individuals (Hofmanová et al. 2016), but the main bulk of data corresponds to the first Neolithic communities from the Carpathian basin belonging to the Cris, Körös and Starčevo cultures (6000–5400 cal BC) (Gamba et al. 2014; Haak et al. 2015; Hervella et al. 2015; Szécsényi-Nagy et al. 2015).

The available information from the Mesolithic genetic background of this region is restricted to the mitochondrial analysis of one individual, attributed to haplogroup U5b2a5, so in line with what has been observed in Iberia and Central Europe (Bramanti et al. 2009; Hervella et al. 2012; Sánchez-Quinto et al. 2012), but still insufficient to make reliable inferences about the hunter-gatherer genetic legacy in the region and its relationship with the Neolithic. Considering the set of haplogroups present in the Pottery Neolithic of Western Anatolia, a demographic input carrying lineages H, K, N1a, T2, W, X2 and J can be assumed (Fig. 12.3). This "mitochondrial Neolithic package" has its origins in Anatolia, but probably not amongst the members of the Fikirtepe culture as discussed above. Its connections with the Early Neolithic from the Aegean are unclear, as mitochondrial data from just one individual is available. Interestingly, the two Aegean Mesolithic individuals that could be successfully analysed belong to the mitochondrial haplogroup K1c, characteristic of Early Neolithic populations (Hofmanová et al. 2016), thus suggesting a possible Mesolithic ancestry of Early Neolithic people from the Aegean.

Distribution of Y chromosome lineages is also in agreement with certain levels of demic diffusion from the first farmers into the Starčevo cultural complex, and haplogroup G2a—present in the studied Anatolian populations—is widely distributed not only in the Starčevo group, but also in Western, Central and Southeastern Early Neolithic cultures (Fig. 12.4). However, basal levels of haplogroup I and its subclade I2a1, both present in Mesolithic hunter-gatherers from Scandinavia (Motala, Sweden) and Luxemburg (Loschbour), are also detected. Lineages I and I2a are represented in the Anatolian Neolithic, making it difficult to ascertain if they were introduced through demographic diffusion or alternatively, if they signify a signature of acculturation of local hunter-gatherer groups.

Genome-wide analyses place the Early Neolithic Körös, Starčevo and Aegean individuals in the vicinity of the Early Neolithic individuals from Anatolia. The relationship between these balkanic cultures and therefore the question of homogeneity vs. regionality cannot be inferred from the data as the Körös samples are pooled together with other individuals from later cultures, like the Alföld Linear Pottery and the Transdanubian LBK (Haak et al. 2015 Fig. 2a; Mathieson et al. 2015 Fig. 1b). One of the two studied samples from the Körös culture (KO2) seems to be more closely related to the Anatolian and Greek Early Neolithic than the individuals from the other cultures according to the new data of Hofmanová et al. 2015. However, the other skeleton found within the context of the Körös culture displays a strong Mesolithic genetic signature, clustering next to the Scandinavian and Iberian hunter-gatherers. The Y chromosome haplogroup of this sample is I2a, also compatible with a Mesolithic origin (Gamba et al. 2014).

Even though the levels of admixture with local Mesolithic groups are difficult to evaluate as the only data available from the region correspond to mitochondrial DNA, in the light of this result we have to consider that together with migration, processes of assimilation might have also played an important role in the adoption of the Neolithic in the region.

The arrival of the Neolithic East of the Balkans has been poorly explored from a Palaeogenetic point of view. The only existing ancient DNA work directly addressing the question of the transition to farming in Ukraine is the one of Jones et al., 2016. In this study genome-wide data extracted from 1 Mesolithic (11,143-10,591 cal BP) and 1 Early Neolithic from the Pit Comb Ware culture (6,469-6,293 cal BP) from the left bank of the Dnieper river were compared. The genetic similarities observed between both were interpreted as evidence of genetic continuity between forager and farming groups, which in principle agrees with the view of a gradual adoption of Neolithic elements by local hunter-gatherers, starting with pottery in the early stages to culminate with a transition to a fully productive economy at the Eneolithic (Matuzevičiūtė 2014).

The only other ancient DNA data available from the same area corresponds to partial and complete mitogenomes from 8 individuals with different datings covering a transect of 2000 years (c. 4000-2300 BCE) of the Eneolithic Trypillian Culture. With the exception of two samples belonging to haplogroup U8b, the majority of these individuals harboured haplogroups absent among European hunter-gatherers (H, H5a, H1b and T2b). Haplogroup U8b has been detected both in the Pottery Neolithic Anatolian samples and in the Upper Palaeolithic, so its presence in the Trypillian sample can suggest either an Anatolian ancestry, as suggested by the authors, but also genetic continuity with local hunter-gatherer populations. On the other hand, the high frequency of haplogroup H places this group of individuals closer to other Funnel Beaker Middle Neolithic cultures (mainly the Salzmünde and the Baalberge) than to other Early Neolithic groups like the LBK or Starčevo.

The small sample size, the lack of resolution of some of the results obtained and the chronological gap existing between the studied samples and the first evidences of farming in the region makes the significance and scope of these works difficult to evaluate. A wider and more representative sampling would be necessary to fully capture the complexity of the transition to farming East of the Danube.

12.6 LBK Cultures and the Neolithisation of Central Europe

The *Linearbandkeramik* (LBK) represents the earliest Neolithic culture in Germany and has its roots in the Starčevo-Cris-Körös cultures of the Carpathian basin. From this region the Neolithic expanded into Central and Eastern Germany through Lower Austria, Moravia and Bohemia (Bocquet-Appel et al. 2009). Current evidence favours colonisation as the main mechanism that brought agriculture to Central Europe, but it has been also argued that the rapid spread of the LBK settlements can only be explained by indigenous acculturation (Bogucki 2000).

The palaeogenetics of the German population has been extensively addressed in different studies covering a time transect from the Upper Palaeolithic to the Early Bronze Age (Bollongino et al. 2013; Bramanti et al. 2009; Brandt et al. 2013; Brotherton et al. 2013; Haak et al. 2008, 2010, 2015; Lazaridis et al. 2014; Lee et al. 2012a, b; Mathieson et al. 2015). During the establishment of farming societies in Germany, mtDNA data suggests a discontinuity between the indigenous hunter-gatherers and immigrant agro-pastoralists, characterised by a lack of local admixture between the two populations and largely mutually exclusive haplogroup compositions (Bramanti et al. 2009; Brandt et al. 2013). The hunter-gatherer mitochondrial background is very homogeneous, consisting exclusively of members of the macro-haplogroup U (U, U2, U4, U5 and U8). However, the majority of

Neolithic lineages belong to haplogroups H, HV, J, K, N1a and T2, with a minor proportion of U3, U5, W and X (Fig. 12.3). With the exception of H and U5, these haplogroups have not been previously described in the pre-Neolithic background, pointing out at a strong genetic input from Neolithic farmers. The decline in hunter-gatherer haplogroups in the transition to farming does not equate a complete replacement, but suggests an integration of those lineages through acculturation processes. Indeed, archaeological samples collected from a site in Hagen, Germany, have revealed that pockets of hunter-gatherers maintained their lifestyle alongside the Neolithic farmers until the Late Neolithic (Bollongino et al. 2013).

The mitochondrial profile of the German LBK is very similar to the Hungarian local manifestation of the LBK, the transdanubian LBK or LBKT, thus supporting a genetic continuity during the initial spread of the agriculture to the Central European plain (Szécsényi-Nagy et al. 2015). Y chromosome and genome-wide analyses echo the same results, but the evaluation of the significance of the different lineages is obscured in this case by the lack of regional comparative data from the Mesolithic background. As previously observed for the Starčevo-Cris-Körös, paternal haplogroups G2a and F* are prevalent both in the LBKT and the LBK. From those, haplogroup F* cannot be traced back to Anatolia, so its origins in the local Mesolithic background or in the incoming Neolithic populations cannot be ascertained. A basal frequency of haplogroup I2a, characteristic of hunter-gatherer groups, is also present in the LBKT but not in the LBK, probably due to the reduced sample size.

A clear differentiation of the LBK, LBKT, Starčevo and Hungarian Neolithic from Western, Eastern and Scandinavian hunter-gatherers can be also observed at a genome-wide level (Haak et al. 2015). Relationships amongst the studied LBK individuals and members of the other cultures are however not so evident, and the data suggest certain levels of population structure and therefore genetic differentiation within the LBK. When compared with the other cultures, the LBK seems to have a much wider genetic variability: while some of the LBK individuals are more similar and even overlap with members of Early Hungarian cultures/Starčevo/LBKT, others are shifted towards the distribution of Iberian Epicardial Neolithic (Haak et al. 2015; Fig. 2; Mathieson et al., Fig. 1). These differences could be tentatively explained through differential levels of admixture with hunter-gatherers at an individual level, as suggested by basal frequencies of mitochondrial and Y chromosome hunter-gatherer haplogroups (Haak et al. 2015; Fig. 3).

12.7 The Cardial/Epicardial Culture and the Neolithisation of Iberia

In Iberia, located in the westernmost edge of the Neolithic expansion route, the extension and varied geography of the territory, the presence of a strong Mesolithic substrate and the chronological differences in the introduction of the Neolithic package that exist between regions, conform a complex pattern that requires the examination of all lines of evidence at a regional scale.

The earliest "Neolithic package" of the Iberian Peninsula is characterised by the presence of impressed (Cardial) pottery in the Mediterranean coasts of Iberia around c. 5900–5400 BCE. The introduction of the Neolithic in the Cantabrian façade took place more than 1000 years later (c. 4100 BCE) than the first arrival of the Neolithic into the Peninsula, and has been traditionally seen as an indigenous process (Price 2000a).

The appearance of the Neolithic in the Atlantic coasts of Portugal is synchronous to the one in the Mediterranean (c. 5750–5500 BCE). This has been interpreted as a sign of a rapid pioneer colonisation by Near Eastern farmers, which could only be achieved through navigation (Zilhão 2001). Interestingly, radiocarbon date distribution of Mesolithic and Neolithic enclaves in Portugal also shows the coexistence of hunter-gatherer and Neolithic groups in certain regions.

Publicly available and validated palaeogenetic data of Mesolithic and Neolithic specimens in Iberia is mainly restricted to four regions: the Cantabrian fringe, Aragón, Catalonia-Valencia and León in Spain and Almonda in Portugal. With the exception of two complete genomes from the Mesolithic site of La Braña and one from the Cardial Neolithic site of Cova Bonica, all the available data correspond to the analysis of mitochondrial DNA (Gamba et al. 2012; Haak et al. 2015; Olalde et al. 2015; Sánchez-Quinto et al. 2012).

The pre-Neolithic background of Iberia is represented by 3 Magdalenian and 3 Mesolithic specimens from the Basque Country and León (Hervella et al. 2012; Sánchez-Quinto et al. 2012). While the 3 Mesolithic individuals display typical hunter-gatherer U lineages, the other 2 belong to haplogroup H. According to these data, the Iberian hunter-gatherer mitochondrial background seems to differ from the homogeneous U-type of Central and Northern Europe due to the high frequency of haplogroup H (29%). A regional genetic differentiation between hunter-gatherer groups across the Cantabric façade, with U5 haplogroups in the West (La Pasiega, La Chora and La Braña) and H haplogroups in the East (Aizpea and Erralla), could possibly explain the presence of haplogroup H in pre-Neolithic Iberia. However, the sample size is not enough to make such a statement.

The transition to the Neolithic in the Cantabrian fringe is marked by the appearance of new mitochondrial haplogroups: HV, I, J, U*, K and X (Fig. 12.3). From these, types H, K, J, T2 and X are common with the Cardial/Epicardial of Catalonia, Valencia and Aragón. Even though the analysis is constrained by the sample size, some regional characteristics can be observed, namely the presence of haplogroup N* in Catalonia and N1a in Aragón. The former accounts for 20% of the variability in the Cardial/Epicardial catalan sample and displays negligible frequencies in modern Europe. As already discussed, these types have not been previously detected in the European pre-Neolithic background, suggesting that they may be part of the "Cardial mtDNA Neolithic package" brought by a wave of genetically distinct Near Eastern farmers to the region. Modern distribution of both haplogroups in the Near East and cultural connections with Syrian Pre-pottery contexts were originally used as arguments to support this observation (Gamba et al. 2012), but the final confirmation of a Neolithic Near Eastern origin came for the finding of one member of haplogroup N*—albeit with a different haplotype—in the PPNB site of Tell Halula (Fernández et al. 2014).

The presence of rare haplogroup N1a in Iberia raises the question of possible connections between the Mediterranean and the central European routes of Neolithic expansion. Indeed, a common origin for the Cardial and the Central and South eastern Neolithic European cultures has been proposed based on the clustering of Cardial/Epicardial genomes from Catalonia (Cova Bonica) and Aragón (Cueva de Els Trocs) with one LBK individual from Germany (Stuttgart) and one from Hungary belonging to the Alföld Linear Pottery complex (NE1) (Olalde et al. 2015). A similar pattern can be observed in Fig. 2 from Haak et al. 2015, where some LBK genomes fall in the vicinity of Epicardial individuals from Els Trocs.

A common origin for the different Early Neolithic cultures in the Balkans would explain the observed genomic homogeneity of Early Neolithic genomes in comparison with differentiated hunter-gatherers (Haak et al. 2015). However, the number of genomes representative of the different periods is still scarce and, as a consequence, the amount of diversity within every culture is difficult to predict.

Cultural contacts should be considered as an alternative explanation for the observed inter-cultural genetic and genomic similarities. Increased individual mobility during the Cardial can be deduced from the long-distance exchange of items like pottery, ground stone and obsidian observed in the archaeological record (Barnett 2000). It has been also proposed that La Hoguette and Limburg pottery traditions, coeval to the early phases of the LBK, have their origins in the Cardial/Epicardial groups of Southern France and North Eastern Spain (Lefranc 2008; van Berg 1990). These ceramic ware types appear at early stages of the LBK settlements on the Rhine and Neckar valleys in Germany (La Hoguette) and eastern France and Belgium (Limburg) and while some scholars see this phenomenon as an adoption from indigenous groups living at the margins of the LBK distribution, for others it represents an exogenous contribution with its roots in the Cardial and Epicardial of southwestern Europe (Bickle and Whittle 2013; Jordan and Zvelebil 2009). What seems clear is that the cultural connections between western Mediterranean and central European Neolithic cultures might have been more frequent than we think. Whether this offers a satisfactory explanation for the observed genetic patterns or not is a question that will have to be addressed when more genomic data from Cardial and Epicardial contexts is produced. In the meantime, the factor of individual mobility as an epitome of cultural (and perhaps genetic) exchanges between cultures should be further acknowledged and explored.

12.8 Late Hunter-Gatherers and Early Farmers in the Transition to Farming in Scandinavia and the Baltic

The Neolithic arrived to Scandinavia at c. 4000 BCE and spread rapidly in less than 200 years. The early farmers of Scandinavia were members of the Funnel Beaker Culture, also known as Trichterbecher Kultur or TRB (Malmström et al. 2009). How farming was introduced in this region has been widely debated, and one key question is the role that local hunter-gatherer groups played in the transition to farming. One example is the Pitted Ware Culture group (PWC) that appeared after the TRB in Scandinavia around 5300 BP and disappeared around 4000 BP, thus coexisting with the farmers for 1000 years. Different theories have been proposed to explain the origins of the PWC, its relationship with the TRB cultures and its connection with modern Scandinavian populations: i) the PWC are descendants of Late Mesolithic communities in Northern Europe, ii) the PWC emerged from the TRB through a reversion to a hunter-gatherer economy and iii) the PWC originated from the ancestral population to the modern Saami group.

Ancient DNA has provided the answer to some of these questions. Overall, mitochondrial DNA analyses indicates a discontinuity between the PWC and the TRB groups. As observed in other regions in Europe, hunter-gatherers harboured high frequencies of haplogroups U, U4 and U5 while farmers displayed H, K, T2 and J types (Malmström et al. 2009; Skoglund et al. 2012, 2014) (Fig. 12.3). However, the presence of J and K haplogroups in both groups, suggests the idea of admixture events between them cannot be discarded. No Y chromosome has been reported for the farming group, but the six hunter-gatherers belonged to haplogroup I2 characteristic of the Mesolithic substrate.

Genome-wide analyses also distinguished the Mesolithic and PWC groups from the TRB, confirming that different subsistence practices in Scandinavia were connected to different genetic backgrounds, and therefore ruling out the possibility that the PWC originated from the TRB. While no significant signatures of admixture with European farming groups could be detected for the PWC, the TRB displayed a substantial amount of ancestry related to European hunter-gatherer populations, indicating that the ancestors of the group probably admixed with hunter-gatherer groups before expanding to Scandinavia (Skoglund et al. 2014). This contact could have occurred at the southern Scandinavian agricultural frontier between local Mesolithic groups, the Etterbølle, and late Danubian farmer groups, as evidenced by traded items of Neolithic origin in the Mesolithic context before the arrival of farming to the region (Price 2000b). However, the possibility of admixture after the introduction of the Neolithic through contact with local hunter-gatherer groups cannot be discarded. The genetic similarity of TRB early farmers to other Early Neolithic cultures and its distinction from Mesolithic and late hunter-gatherer groups allows us to discard pure acculturation processes as the main mechanism of transition to agriculture in the region. In the light of the obtained results, more complex models of interaction, including genetic exchange, should be considered.

The Neolithisation of the Baltic region followed a similar pattern to peninsular Scandinavia, and was defined by a slow and gradual process of introduction of agricultural practises (Zvelebil 2006). Even though certain elements of the Neolithic package arrived as early as 6000-4500 , a fully farming economy was not fully established until *c*. 4400 BC (Jones et al. 2016).

The comparison of genome-wide SNP data from 3 Late Mesolithic (*c*. 8400-6800 cal BP) and 2 Middle Neolithic (*c*. 6200-5700 cal BP) skeletons from Latvia supports a process of adoption of agriculture by local hunter-gatherer groups, as the genomes of both groups fall within the same cluster and no evidence of admixture with European or Anatolian Early farmers is detected (Jones et al. 2016). All the studied samples fall within U mitochondrial haplogroups, so in agreement with the pattern observed at genomic level. However, as noted by the authors, the absence of an Early Neolithic genetic component in these individuals could be also explained through networks of genetic exchange with local hunter-gatherer groups. Whether these results represent a pattern that can be extrapolated to the whole Baltic area or not cannot be answered with the available data.

12.9 Ancient DNA and the Neolithisation of Europe: Lessons Learnt and Future Challenges

Along these lines, plenty of evidence has been provided about the potential of palaeogenetic analyses in the Neolithisation debate. However, the resolution of the conclusions achieved is dependent on the level of completeness of the Neolithic genetic map, which in turn is a consequence of sample availability and DNA preservation in archaeological contexts. Even though new high throughput sequencing techniques continue to push the boundaries of DNA retrieval, the high sequencing costs makes this approach affordable only for these skeletal remains in which a good fraction of endogenous DNA is preserved.

While certain regions, like Saxony-Anhalt in Germany, have been extensively studied, other key areas in the Neolithisation process like the Levant, Anatolia, the Adriatic, Thyrrenean and Ligurian coasts still remain poorly unexplored. Despite these gaps in the Neolithic, current information is accurate enough to draw the following conclusions about the transition to farming with a certain level of confidence:

1. Compared to the Early Neolithic, the mitochondrial and Y chromosome genetic background of hunter-gatherer populations was rather homogeneous, with a high frequency of U-derived haplogroups for mitochondrial DNA and I haplogroup for the Y chromosome.
2. At a genome-wide level, hunter-gatherer populations were geographically stratified, probably as a result of small population size and genetic drift.
3. The arrival of farming in Europe was overall accompanied by a genetic replacement observable at genome-wide, Y chromosome and mitochondrial DNA levels and resulting from a population input from the Near East.

4. This genetic replacement linked to the arrival of the Neolithic was not complete, and a survival of certain levels of hunter-gatherer ancestry can be demonstrated for mtDNA (haplogroups U5 and H), Y chromosome (haplogroup I) and genomic SNPs in different geographical regions.
5. Together with colonisation, acculturation and admixture events contributed to the Neolithic spread in Europe.
6. Post-Neolithic events have erased the original Neolithic signature in modern Near Eastern and European populations, questioning the usefulness of modern populations to make inferences about the Mesolithic-Neolithic transition process.

One of the most important lessons learnt from the genetic approach to the study of the origins of European populations is that the current knowledge on the topic is not "set in stone". The continuous addition of data is constantly refining the Neolithic genetic map, forcing a frequent reinterpretation of previously proposed hypotheses in an attempt to approximate the real process underlying the transition to a farming economy in Europe.

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Chapter 13
Paths and Rhythms in the Spread of Agriculture in the Western Mediterranean: The Contribution of the Analysis of Harvesting Technology

Juan José Ibáñez-Estévez, Juan Francisco Gibaja Bao, Bernard Gassin, and Niccolo Mazzucco

13.1 Introduction

It is well established that the Near East was the first focus of the development of agriculture. Early experiences in cereal cultivation took place there during the PPNA and the first genetically modified cereals appeared in the Early PPNB. Morphologically domestic species began to be dominant in cereal assemblages around the end of the 8th millennium cal BC. From that time on, agriculture began to spread into Europe and central Asia (Willcox 2012).

Most of the debate on the spread of agriculture into Europe is centered on the mechanisms of expansion, with models proposing the demic diffusion of farming populations (Ammerman and Cavalli-Sforza 1971), while others suggest cultural transmission (Zvelebil 1986) with an array of intermediate alternatives (Zvelebil and Lillie 2000). In demic diffusion models, which imply a regular rhythm of expansion and the substitution of the original populations by the newcomers, the rhythm of spread depends basically on population growth. Mathematical modeling of demic diffusion has demonstrated its plausibility. However, subsequent work has also shown mathematically that identical traveling waves for the spread of farming can be generated by models comprising the incorporation of hunter-gatherer populations to the Neolithic expansion wave through acculturation (Aoki et al. 1996).

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The spatial transfer of the *new way of life* associated with the Neolithic (including, but not only, agriculture and livestock) cannot take place by distant transmission through an exchange network, as complex cultural systems need direct and durable experience to be transmitted. Thus, Neolithic and associated agriculture displacement should imply either the movement of colonizing groups and/or the stable interaction of hunter-gatherer local populations with the Neolithic newcomers and the subsequent learning by the original populations. Genetic studies on humans and animals are showing that population and livestock movement from the east played an important role in the process (Brandt et al. 2013). However, the arrhythmic nature of the movement (Guilaine 2003), proofs of interbreeding with eastern and western genes in humans and animals (Krause-Kyora et al. 2013), and appearance of cultural derivations in the movement from east to west (Guilaine 2003; Rigaud 2011) suggest that the exclusively demic explanation is too simple and a certain and geographically variable degree of interaction between farmers and hunter-gatherers took place.

If the mechanisms and the rhythms of the Neolithic expansion are widely discussed, the paths of this expansion are addressed less and they are still poorly understood. Two main currents of E-W expansion have been identified: a Northern one, crossing central Europe, and a Southern one along the Mediterranean coast (Alexander 1978). For the Western Mediterranean, J. Zilhão has proposed a quick Neolithic colonization by leapfrogging pioneer groups who followed maritime routes from Italy to the Atlantic coast of Portugal, passing through the Gulf of Lyon, the Spanish Levantine coasts, and the Strait of Gibraltar, and constituting isolated farming communities in contact with local hunter-gatherer groups (Zilhão 2001).

This idea of the introduction of the Neolithic in the Western Mediterranean, and more specifically in the Iberian Peninsula, from the North has been dominant during recent decades, replacing the southern alternative, the idea of the Neolithic coming from North Africa. Nonetheless, some new data are reincorporating the latter idea into the current debate (Gibaja and Carvalho 2010; Manen et al. 2007; García Borja et al. 2011). However, the reasonable hypothesis of the Neolithic expansion from the Northern African coast is still waiting for new hard data in terms of archaeological levels clearly corresponding to peasant communities and dating to the first half of the 6th millennium.

During recent decades, pottery morphology and decoration, combined with C14 dates, have been used for the study of cultural affinities between Neolithic groups and as the main tracer to follow its expansion from east to west around the Mediterranean Basin (Manen 2002). Neolithic groups with Impressa pottery settled in SE Italy at the beginning of the 6th millennium BC (Guilaine and Manen 2007) and expanded into central Italy, Corsica, and Sardinia (D'Anna et al. 2001; Binder and Maggi 2001; Lugliè 2009), soon afterwards (Ferrari et al. 2001; Fugazzola Delpino et al. 2003). It is currently well established that some pioneering farming groups traveling from central/southern Italy settled on the Ligurian (Arene Candide; Maggi et al. 1997), Provenzal (sites of Pendimoun and Caucade; Binder and Senepart 2010), and Languedocian coasts (sites of Peiro Signado and Pont de

Roque Haute; Briois and Manen 2009; Guilaine et al. 2007) about 5800 cal BC, using Impressa ware. Around 5600–5550 cal BC some Neolithic groups also using Impressa ware are documented in Valencia (sites of Barranquet and the older phase at Mas d'Is; Bernabeu et al. 2009; Bernabeu and Martí 2014). Impressa pottery displays different styles at each site, so these pioneering groups probably came from different origins in the central/south Italian area (Manen 2002; Guilaine and Manen 2007). Cardial pottery appears on the Ligurian, Provenzal, and Languedocian coasts around 5450 cal BC (Binder and Senepart 2010) and at a similar time on the Levantine Spanish coast (Oms et al. 2014). Several hypotheses try to explain the origin of the Cardial groups: (1) as a second population wave from an external origin (probably the Tyrrhenian cardial), (2) as the result of the acculturation of hunter-gatherer populations in contact with the Impressa Neolithic groups, or (3) as a continuity of Impressa groups (Guilaine and Manen 2007). Parallel to the appearance of the first Cardial groups in the Gulf of Lyon, around the mid-6th millennium BC, farming communities, classified as the Friuli and Fiorano complexes, are for the first time present in continental NE Italy, using incised/ impressed pottery. Indeed, during the second half of this millennium (from 5300 cal BC; Manen 2002), the Epicardial (or Pericardial) complex, with incised/impressed pottery, appears in the hinterland of the Gulf of Lyon (including Catalonia) and inland areas of the Iberian Peninsula, and for some centuries is coetaneous with the Cardial complex (Binder 1995; van Willigen 1999; Bernabeu and Martí 2014). This Epicardial complex has been explained as the result of the acculturation of Mesolithic groups in contact with the cardial-Neolithic coastal communities (Van Willigen 2004). In the Iberian Peninsula, at the end of the 6th millennium three geographical entities with different pottery stylistic traditions are evident: one with Cardial pottery, on the Levantine coast and some areas of the Portugal Atlantic coast; one with Almagra pottery in Andalusia and southern Portugal; and one with line-impressed pottery (Boquique) in the inner Iberian Peninsula (Aura et al. 2010; Alday 2009). This diversity at the end of the 6th millennium is also observed in SE France, where a mosaic of cultural complexes is identified based on pottery styles between 5250 and 4700 cal BC, with Epicardial, Cardial, and an early phase of the VBQ pottery (Binder and Sénépart 2010).

The analysis of pottery styles offers very relevant data on cultural affinities. However, the view of Neolithic expansion which can be defined from the analysis of pottery styles is very complex, as pottery characteristics and decoration are very dynamic cultural elements, so they can change considerably in a short lapse of time. Moreover, pottery can be easily shared and copied between different cultural groups (Barnett 1990). Because of this, the use of pottery styles can be complemented with other information about more conservative cultural trends, such as those related to subsistence practices, which, studied within the geographical and chronological framework, can offer an image of *longue durée* of the Neolithic expansion.

The analysis of the characteristics of harvesting technology used by the first groups of farmers and its distribution and spread in the Western Mediterranean can offer fresh data greatly contributing to the debate on the expansion of agriculture.

For the transmission of agriculture, seeds must be associated with the complex technology needed to cultivate, reap, store, and consume them. Among farming communities, agricultural technology is traditionally very conservative, as it is a strategic activity related to the survival of the group, so only well-proven innovations, implying small risks of failure, are adopted (Juma et al. 2009).

Ethnography shows that the agricultural process, and more specifically cereal harvesting, can be carried out in many different ways (Hillman 1984; Sigaut 1978; Peña-Chocarro et al. 2009). Harvesting can be done without resorting to specialized tools, by uprooting the whole plant or by picking the ears by hand. In other cases involving the cultivation of hulled wheat, tools used to plucking the ears, like the *mesorias* in Asturias, can be used. More commonly, cutting tools (sickles) are used as harvesting tools. But even among sickles, many technical variants are possible: the cereal can be cut high or near the ground, cereal stems can be gathered with the bare hand before cutting them, the same sickles can be used for gathering up the stems before cutting, and so on. This variability in harvesting technology can be explained by different factors, such as the type of crop, climate variables, and size of the cultivated fields (Ibáñez et al. 2008), or can simply be the result of choices based on cultural traditions. In any case, harvesting is strategic and stable, and is therefore a good tracer to identify groups of farmers with similar or divergent agricultural technical traditions. However, ethnographic examples also show that, when two groups share similar technical systems and one of them decides to adopt some technical element from the other, the shift can be very fast (Raynaut 1984).

This chapter studies the harvesting techniques in several Neolithic sites in Italy, southern France, and the Iberian Peninsula. The observed patterns are cross-referenced with variables which can influence harvesting technology (cereal type, climate, and cultural traditions). As we shall see, this last variable best explains the observed diversity, offering valuable information on the paths and, when comparing the information with C14 data, on the rhythms followed by human groups with different technical harvesting traditions who took specific types of sickles with them in their expansion along the Western Mediterranean.

13.2 Methods and Materials

Reaping cereals with sickles doted with flint insertions produces a characteristic macroscopic gloss in the edge of the flint tool after several hours of working. The presence of glossed tools among the first farmers in Europe shows the relevance of cereal harvesting with sickles in this early agriculture. Apart from harvesting, other activities can generate macroscopic gloss on lithic tools. However, specific harvesting gloss can be identified through microscopic analysis.

Most of the Neolithic sickles were made from wood, so we have a limited knowledge of the characteristics of the whole tool. However, the exceptional preservation of wooden sickles in waterlogged sites like La Draga, La Marmotta, or some Swiss sites allows the preservation of complete tools. Sickles can also be preserved in dry caves, like Los Murciélagos in Albuñol (Andalusia), or when they are made from antler (Flors et al. 2012). When the whole sickle is not preserved, the characteristics of the lithic insertion and the distribution of gloss on its edges can offer information on how it was inserted in the sickle shaft. The analysis of the flint insertions from Neolithic sites and their comparison with the exceptionally preserved whole sickles affords a detailed reconstruction of the first harvesting techniques in the Neolithic.

This chapter brings together the results of a large group of use-wear analysts who have been working on the subject in the last decade (Ibáñez et al. 2008; Gassin et al. 2010; Gibaja et al. 2014). Sickle elements were submitted to macroscopic and microscopic observation with stereo- and metallographic microscopes, following the standard methodology of use-wear analysis (González Urquijo and Ibáñez 1994; Gassin 1996; Gibaja 2003). All the macroscopically glossed tools at our disposal from several early Neolithic sites in Iberia, southeast France, and Italy were analyzed. Most of the sites have been analyzed by the authors, while others were studied by colleagues, specialists in use-wear analysis (Table 13.1). For some sites, the drawings of sickle elements showing the distribution of gloss, produced by specialists in lithic technology, are very explicit, allowing precise determination of the type of sickles in which the elements were inserted. These sites are listed in another table (Table 13.2).

13.3 Results

Several different types of sickles were used in the Western Mediterranean during the Early Neolithic.

13.3.1 La Marmotta Sickle Type

These are curved sickles with small oblique flint insertions creating toothed edges. The curved form of the sickle was used to gather the stems, which were held in the bare hand before cutting them with a slightly curving motion, as is still carried out in some areas of the Southern Mediterranean with iron sickles.

One complete sickle of this type was found in the mid-19th century in the dry cave of Los Murciélagos de Albuñol (Granada). The tool is not preserved but we have a drawing made by M. de Góngora (1868/1991) which followed the description of one of the discoverers. The sickle was curved and the cutting edge, made with flint elements, was toothed. Several whole sickles of this type have been discovered in the waterlogged lake site of La Marmotta in central Italy (Fugazzola Delpino et al. 1983; Fig. 13.1).

Flint elements fitted into these sickles are, normally, between 2 and 3 cm long, and around 1 cm wide, though some of the elements can be up to 5 cm long

Table 13.1 Early Neolithic archaeological sites studied in this chapter. Information provided includes the region where the site is located, the "culture" to which the site is attributed, the main C^{14} dates, the number of sickle elements corresponding to the three types of sickles, and the presence of abrasive microwear traces (Rv2)

				Chronology (BP)			Sickle elements with use-wears				
State	Site	Region	Culture	str.	lab	date	*Oblique multiple*	*Oblique single*	*Parallel*	*Rv2*	*Indet*
Italy	Arene Candide	Liguria	Impressa	str. 15 (TIN)	UB-2424	6700 ± 145	1 (doble use)	0	0	0	0
				str. 27 G (LBB)	Beta-66553	6880 ± 60	0	0	0	0	3
				str. 24 G1 (LBB)	Beta-60686	5910 ± 90					
			Vasi Bocca Quadrata	str. 22 H (LBB)	Beta-60699	5970 ± 100	0	0	16	0	2
				str. 20 H (LBB)	Beta-60698	5860 ± 90					
				str. 19 H (LBB)	Beta-60697	5850 ± 90					
	Isorella	Lombardia	Gruppo del Vhò	pit 1	GrN-23645	5850 ± 80	0	0	5	0	0
	Sammardenchia	Friuli	Friulan Neolithic group	pit 87	R-2547	6570 ± 74	0	0	48	11	7
				pit 126	R-2931	5713 ± 49					
	Piancada	Friuli	Friulan Neolithic group	Burial area	Ozc-211	6330 ± 50	0	0	31	3	0
	Cialdino	Toscana	Impressa/Incisa	No data	No data	6460 ± 35	1	0	0	0	0
				No data	No data	6375 ± 35					
	Trasano	Basilicata	Impressa	N.I-C3	Tan-88248	6980 ± 130	6	0	2	7	2
				N.I-C2inf.	Tan-88313	6790 ± 120					
				N.II-C2	Lyon-4409	6950 ± 190	16	0	1	10	7
				N.II-C2	Tan-88068	6660 ± 150					

	Torre Sabea	Puglia	Impressa	Zona A, 2 inf	TAN-88067	6950 ± 130	17	0	0	6	9
	Mileto	Toscana	Fiorano/Incisa	pit. 1	Beta-44114	6180 ± 80	0	1	0	0	0
				pit. 2	Beta-44155	6100 ± 80					
	Pizzo di Bodio	Lombardia	Gruppo dell'Isolino	str. 1	No data	6320 ± 80	0	0	0	0	0
						6060 ± 50					
				str. 2	No data	5730 ± 40	0	0	2	0	1
						5710 ± 90					
	La Starza	Campania	I-Guadone	Niveau VII-VIII-IX	Dsa 330	7087 ± 81			3		
			II-Guadone-Masseria la Quercia	No radiocarbon data			0	0	1	0	
			I ou II	No radiocarbon data					2		3
Spain	La Draga	Catalonia	Early Neolithic (cardial)	Sector C	Beta-278255	6270 ± 40	0	8	15	6	0
				Sector B	OxA-20231	6163 ± 31					
	San Pau del Camp	Catalonia	Early Neolithic (cardial)	Settlement area (pits 1-2)	Beta-236174	6290 ± 50	0	1?	9	6	2
					Beta-236175	6250 ± 40					
			Early Neolithic (postcardial)	Burial area	UBAR-263	5160 ± 130	0	0	2	6	3
	Cova del Frare	Catalonia	Early Neolithic (cardial)	C5c	I-13030	6380 ± 310	0	0	2	8	5
				C5 pit	MC-2298	5800 ± 130					
	Minas 16 de Gavà	Catalonia	Middle Neolithic	U.S. 2	Beta 268776	5190 ± 40	0	0	1	2	1
				U.S. 3	Beta 268777	5030 ± 40					
	Bòbila Madurell	Catalonia	Middle Neolithic	Pit-B12	UBAR-84	5010 ± 80	0	0	3	22	5
				Pit-1	UBAR-6	4970 ± 80					
				BM-G17	UBAR-442	5310 ± 90	0	0	4	45	15
				BM-M7	UBAR-443	4560 ± 80					

(continued)

Table 13.1 (continued)

State	Site	Region	Culture	Chronology (BP)			Sickle elements with use-wears				
				str.	lab	date	*Oblique multiple*	*Oblique single*	*Parallel*	*Rv2*	*Indet*
	Plansallosa	Catalonia	Early Neolithic (epicardial)	N.I	Beta-74311	6180 ± 60	0	0	2	0	0
				N.II	Beta-87965	5720 ± 70					
	Guixeres de Vilobí	Catalonia	Early Neolithic (cardial)	A	OxA-26068	6655 ± 45	3	0	0	0	0
				A	OxA-26069	6536 ± 36					
			Early Neolithic (postcardial)	No radiocarbon data			3	0	0	0	4
	Pla del Riu Marcetes	Catalonia	Middle Neolithic	No data	No data	5040 ± 100	0	0	0	1	2
	Costamar	Valencia	Early Neolithic	str. 130	UCI-AM 60738	5965 ± 25	0	0	2	0	1
				str. 401-654	OxA-V-2357-8	5996 ± 38					
	Cova Sarsa	Valencia	Early Neolithic (cardial)	No data	OxA-V-2392-26	6341 ± 30	13	0	0	0	0
	Cova de l'Or	Valencia	Early Neolithic (Cardial)	J4/c17a	OxA-10192	6310 ± 70	32	0	0	0	0
				H3/c7	H-1754/1208	6265 ± 75					
	Mas d'Is	Valencia	Early Neolithic (cardial/impressa)	House2-80205/ UE80205	Beta-16672	6600 ± 50	12	0	0	0	3
				pit5-99014	Beta-171907	5550 ± 40					
	El Barranquet	Valencia	Early Neolithic (impressa)	UE79	Beta-221431	6510 ± 50	6	0	0	0	0
				UE79	Beta-239379	6510 ± 50					
	Murciélagos de Zuheros	Malaga	Early Neolithic	IV	GrN-6169	6150 ± 45	3	0	0	0	0
				IV	GrN-6639	6025 ± 45					

	Castillejos de Montefrío	Andalusia	Early Neolithic	Fase 1	Ua-36215	6310 ± 45	4	0	0	0	0
				Fase 6	Ua-36212	6240 ± 45					
	Bajondillo	Andalusia	Early Neolithic	No data	Wk-27461	6234 ± 30	1	0	0	0	0
				No data	Wk-25172	6185 ± 30					
	Cueva Nerja	Andalusia	Early Neolithic	NV3 (Fosa)	Beta-131577	6590 ± 40	2	0	0	1	0
			Early Neolithic	NM10	OxA-26085	6342 ± 37	1	0	0	0	0
				NM7techo	Beta-270019	6040 ± 40					
	El Castillo de Doña Mencía	Andalusia	Early Neolithic		No radiocarbon data		1	0	0	0	0
	La Vaquera	Castilla-Leon	Early Neolithic	str. 94	GrA-9226	6440 ± 50	0	4	3	3	0
				str. 98	GrA-8241	6080 ± 70					
	La Revilla del Campo	Castilla-Leon	Early Neolithic	str. 14	KIA-21358	6365 ± 36	0	2	1?	1	11
				str. 4	UtC-13348	6120 ± 60					
	La Lámpara	Castilla-Leon	Early Neolithic	Pit 18	KIA 21347	6407 ± 34	0	6	0	0	8
				Pit 1	KIA-6789	6055 ± 34					
	Casa Montero	Madrid	Early Neolithic	CM/05/95/D4/16303/1	Beta-232890	6500 ± 40	0	2	0	0	0
				CM/05/95/D2/8142/1	Beta-232888	6240 ± 40					
	Los Cascajos	Navarra	Impressa	N.I-Hearth 551	Ua-24428	6435 ± 45	2?	0	5	16	1
			Cardial	N.II-Hearth 31	GrA-16942	5100 ± 50	18	0	0	0	2
France	Pendimoun	Provence	Impressa	US.5711	Lyon-1713 (GrA-20195)	6790 ± 50	0	0	1	0	1
				US. 2067	GrA-26897	6500 ± 40					
			Cardial	US 5557	GifA-101340	6450 ± 90	0	0	3	0	1
	Peiro Signado	Languedoc	Impressa	St 7	Ly-8399	6770 ± 55	17	0	0	0	13
				St 1	Ly-8400	6840 ± 55					

(continued)

Table 13.1 (continued)

State	Site	Region	Culture	Chronology (BP)			Sickle elements with use-wears				
				str.	lab	date	*Oblique multiple*	*Oblique single*	*Parallel*	*Rv2*	*Indet*
	Fontbregoua	Provence	Cardial	FH2-9/10	GrA-38336	6390 ± 40	1	0	6	0	0
				FH2-11	GrA-38334	6240 ± 35					
	Baratin	Provence	Cardial	St.8 F3	Lyon-4725	6355 ± 40	3	0	3	1	0
				ST 5	Lyon-99	6145 ± 70					
	Petites Bâties	Provence	Cardial	STR 7192	Beta-130862	6290 ± 50	0	2	5	1?	8
				STR 13837	Beta-130867	6230 ± 50					
	Mas de Vignoles	Languedoc	Epicardial ancien	US 1005	Erl-9580	6182 ± 56	0	1	3	0	2
				US 1005	Erl-9579	6048 ± 56					
	Grotte Lombard	Provence	Cardial	C.5A	Lyon-4156 (SacA-7413)	6280 ± 30	0	1	0	0	0
				C.5	Lyon-4157 (SacA-7414)	6165 ± 35					
	Mourre de la Barque	Provence	Cardial	Couche C6-14 G.3	ETH2647	6305 ± 55	0	0	0	0	1
					ETH 27978	6165 ± 65					
				Couche D4-16	ETH 27980	6285 ± 65					
					ETH 27981	6065 ± 65					
	Strette	Corse	Impressa/cardial	Strette I c. XIV	No radiocarbon data		0	0	1	0	0
	Basi	Corse	Impressa/cardial/ Basien	C7	No radiocarbon data		0	1	1	0	0
Portugal	Cortiçois	Ribatejo	Early Neolithic	No radiocarbon data			9	0	0	0	0
	Vale Pincel I	Alentejo	Early Neolithic	2B	Beta-164664	6740 ± 40	31	0	0	0	0
					Beta-165945	6350 ± 40					
Greece	Franchthi	Peloponnese	Early Neolithic	FF1 42 B1	P–1525	7700 ± 80	2	1?	17	0	3
				H 37 Y	P–1667	7280 ± 90					
			Middle Neolithic	No radiocarbon data					6		

Table 13.2 Early Neolithic archaeological sites analyzed by specialist of lithic technology or use-wear analyses from which the type of sickle is provided or can be inferred from the drawings of the sickle elements

Site	Culture	Region	Sickle's type	Reference
Favella della Corte	Impressa	Calabria	Multiple diagonal and single parallel	Tinè, V. (2009). Un villaggio del Neolitico antico nella Sibaritide. Studi di Paletnologia III, Collana del Bullettino di Paletnologia Italiana. Roma: Istituto Poligrafico e Zecca dello Stato, 625p.
Ripatetta	Impressa	Puglia	Multiple diagonal and single parallel	Giampietri A. & Tozzi C. (1990). L'industria litica del villaggio di ripa tetta (Lucera). Atti Convegno Nazionale sulla Preistoria, Protostoria e Storia della Daunia 11: 57–78.
Coppa Nevigata	Impressa	Puglia	Multiple diagonal	Ronchitelli, A. (1987). L'industria litica. In S.M. Cassano, ed., Coppa Nevigata e il suo territorio. Roma: Quasar Edizioni, 56–58.
La Marmotta	Impressa	Lazio	Multiple diagonal	Fugazzola Delpino, M.A., D'Eugenio, G. & Pessina, A.(1993). "La Marmotta" (Anguillara Sabazia, RM). Scavi 1989. Un abitato perilacustre di età neolitica. Bullettino di Paletnologia Italiana 84: 5–115.
Villaggio Rossi	Impressa	Abruzzo	Multiple diagonal	Moroni Lanfredini, A. & Ronchitelli A.M. (1998). L'industria litica del Villaggio Rossi a Marcianese (Chieti) nell'ambito della facies neolitica a ceramica impressa dell'Italia centro meridionale adriatica, Origini XXI: 67–141.
Colle Santo Stefano	Impressa	Abruzzo	Multiple diagonal	Radi, G. & Danese, E. 2003. L'abitato di Colle Santo Stefano di Ortucchio (L'Aquila). in Atti della XXXVI Riunione Scientifica dell'I. I.P.P, Preistoria e Protostoria dell'Abruzzo, Chieti-Celano, 27-30 settembre 2001. Firenze: I.I.P.P., 145–161.
Grotta San'Angelo	Impressa	Abruzzo	Multiple diagonal	Di Fraia, T. & Grifoni Cremonesi, R., ed., 1996. La grotta Sant'Angelo sulla Montagna dei Fiori (Teramo). Roma: Istituti editoriali e poligrafici internazionali.
Maddalena di Muccia	Impressa	Marche	Multiple diagonal	Radi, G., Negrino, F., Petrinelli, C., Angeli, L. (2005). Osservazioni sull'industria litica di Maddalena di Muccia, neolitico antico. In Atti

(continued)

Table 13.2 (continued)

Site	Culture	Region	Sickle's type	Reference
				della XXXVIII Riunione scientifica dell'I.I.P.P.: preistoria e protostoria delle Marche: Portonovo, Abbadia di Fiastra, 1-5 ottobre 2003 : vol. I-II Firenze: I.I.P.P., 231–244.
Fornace Cappuccini	Impressa	Emilia-Romagna	Multiple diagonal	Bermond Montanari G., Massi Pasi M., Mengoli D. (1994). L'insediamento neolitico di Fornace Cappuccini di Faenza (Ravenna). Preistoria Alpina 27: 173–195.
Valer	Gruppi Veneto-Friulani	Veneto	Single parallel	Fasani, L., Biagi, P., D'Amico, C., Starnini, E. & Voytek, B.A. (1993). Stazione neolitica a Valer (Azzano Decimo-Pordenone): rapporto preliminare degli scavi. in Atti della Società per la Preistoria e Protostoria della regione Friuli-Venezia Giulia, VIII, 97–113.
Campo Ceresole-Vhò di Piadena	Vhò	Lombardia	Multiple diagonal	Biagi, P. & Voytek, B.A. (1992). The flint assemblages from Pits XVIII and XXXII of the Early Neolithic site of Campo Ceresole at Vhò di Piadena (Cremona, northern Italy). Natura Bresciana 27: 243–288.
Ostiano Dugali	Vhò	Lombardia	Multiple diagonal and single parallel	Voytek, B.A. (1995). The Microwear Analysis. in P. Biagi & G. Clark, eds., L'insediamento neolitico di Ostiano-Dugali Alti (Cremona) nel suo contesto ambientale ed economico. Brescia: Monografie di Natura Bresciana 22: 51–86.
Brignano Frascata	Vhò	Lombardia	Single parallel	D'Amico, C., Starnini, E. & Voytec, B.A. (1995). L'industria litica di Brignano Frascata (AL): dati paleoeconomici di un insediamento nel Neolitico Antico attraverso l'analisi tipologica, funzionale e lo studio della provenienza delle materie prime. Preistoria Alpina, 31: 91–124.
Colle Cera	Catignano	Abruzzo	Multiple diagonal	Colombo M., Serradimigni M., Tozzi C. (2008). Un nuovo villaggio della cultura di Catignano : il sito di Colle Cera presso Loreto Aprutino (Pescara), Origini XXX: 57–98.

(continued)

Table 13.2 (continued)

Site	Culture	Region	Sickle's type	Reference
Murcielagos de Albuñol	Neolítico Antiguo	Granada	Multiple diagonal	Vayason, A. (1918-1919). Faucille préhistorique de Solférino. Etude comparative. L'Anthropologie 29: 393–422.
Cueva del Toro	Neolítico Antiguo	Granada	Multiple diagonal	Rodríguez Rodríguez, A.C., Martín Socas, D., Cámalich Massieu, MªD. y González Quintero, P. (1996). Las actividades tecnoeconómicas en "Cueva del Toro" (Antequera, Málaga) a través del análisis funcional. Rubricatum 1: 161–167.
Atxoste	Neolítico Antiguo	Álava	Single parallel	Alday, A., Castaños, P., Perales , U. 2012. "Quand ils ne vivaient pas seulement de la chasse: preuves de domestication ancienne dans les gisements néolithiques d'Atxoste et de Mendandia (Pays Basque). L'Anthropologie 116(2): 127–147.

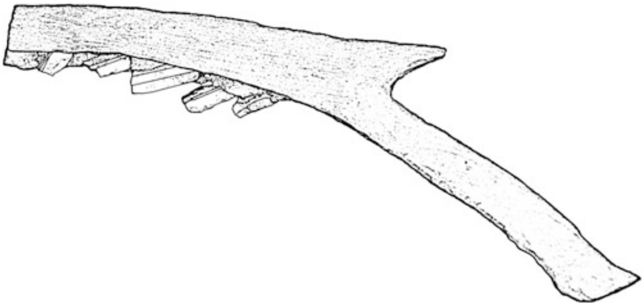

Fig. 13.1 One of the sickles found in the Early Neolithic waterlogged site of La Marmotta (Lazio, Italy), with multiple flint elements in oblique insertion (modified from Fugazzola Delpino et al. 1993)

(Gibaja et al. 2010; Fig. 13.2). Fragments of blades or bladelets intentionally broken were used to obtain this type of cutting element. Typically, the sickle gloss on the flint elements in these sickles is distributed along two-thirds of the cutting edge, appearing as a narrow line on the edge, while it gets more invasive towards one of the extremities of the element. The other extremity is free of use-wear polish. This distribution of use-gloss indicates that blade fragments were inserted into the sickle haft obliquely. The area free of use traces was beneath the mastic which glued the element to the shaft, while the opposite extremity protruded for cutting the cereal stems. At the site of Los Murciélagos de Zuheros, in a context of very good preservation of the organic material because of the dry conditions inside the cave, the distribution of mastic remains on several sickle elements confirms that this type of short sickle element was inserted obliquely (González Urquijo et al. 2000; Gibaja et al. 2012). On one of the sickle elements where the mastic is especially well

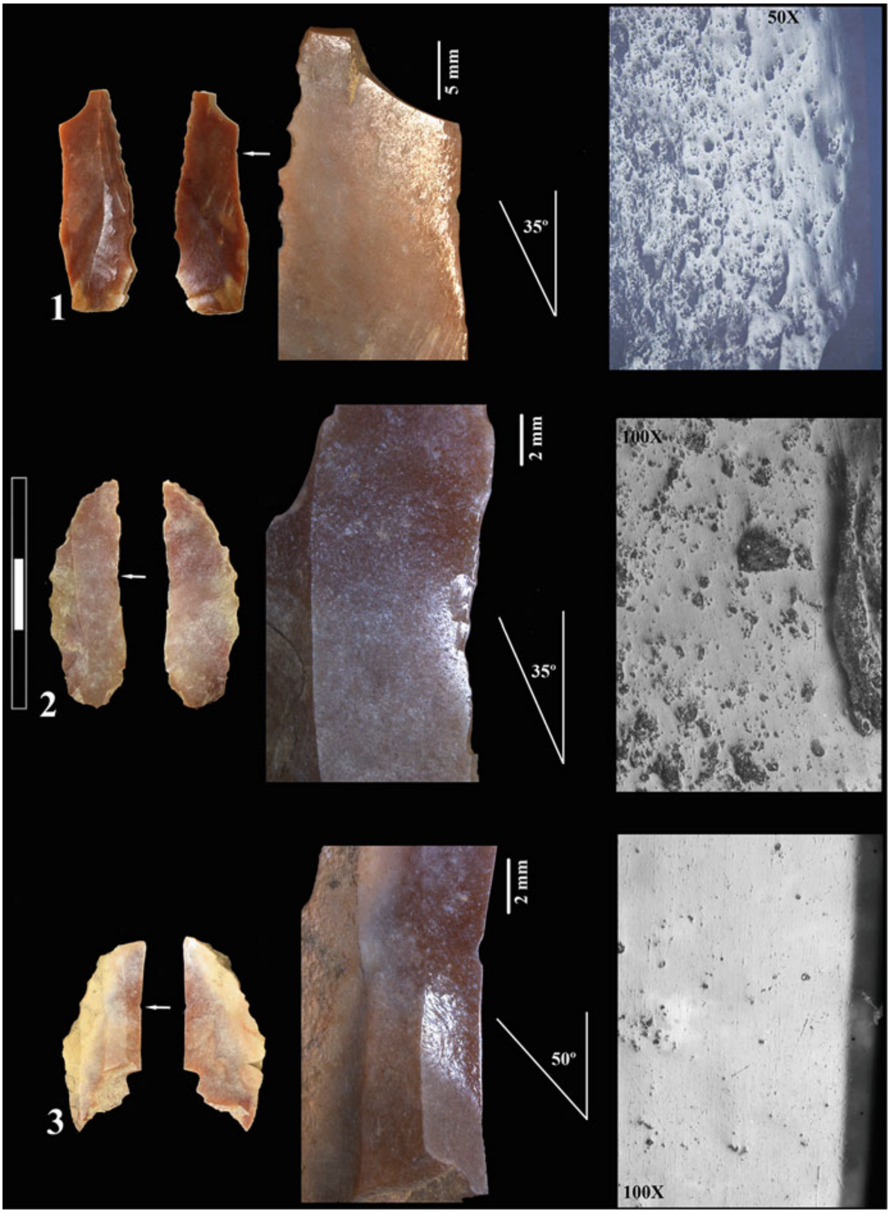

Fig. 13.2 Sickle elements from Cortiçois (Estremadura, Portugal), corresponding to sickles with multiple flint elements in oblique insertion

Fig. 13.3 Several wooden sickles from the waterlogged site of La Draga (Banyoles, Girona, NE Spain; Palomo et al. 2011)

preserved, the shape of the base of the mastic remains shows that there was a groove in the shaft to facilitate the hafting of the flint elements.

13.3.2 La Draga Sickle Type 1

These are L-shaped sickles formed by a straight shaft, a transversal branch, and a long flint blade inserted parallel to the straight shaft. The side branch is used to gather together the cereal stems, which are then held in the bare hand. At the same time, the sickle is turned 90°, so the sickle blade faces the bundle of cereal stems which are then cut. It is thus a kind of two-stage harvesting action, the first to gather the stems and the second to cut them, after turning the sickle.

Several wooden sickles of this type have been preserved in the waterlogged site of La Draga (Banyoles, Girona, NE Spain) (Bosch et al. 2006; Palomo et al. 2011; Fig. 13.3). The wood types used at La Draga are mainly box (*Buxus sempervirens)* and occasionally elder *(Sambucus* sp.) and juniper *(Juniperus* sp.). Flint elements fitting in these sickles are represented by longer blades, between 5 and 10 cm long, with sickle gloss distributed parallel to the edge (Fig. 13.4). Shorter blades can be inserted in these sickles, but, in this case, more than one blade is mounted in the shaft.

13.3.3 La Draga Sickle Type 2

These sickles are used in the same way as La Draga 1 sickles, but, in this case, the long flint blade is inserted obliquely to the straight shaft of the sickle. This type of oblique insertion offers an advantage over the parallel one (La Draga 1) as it allows

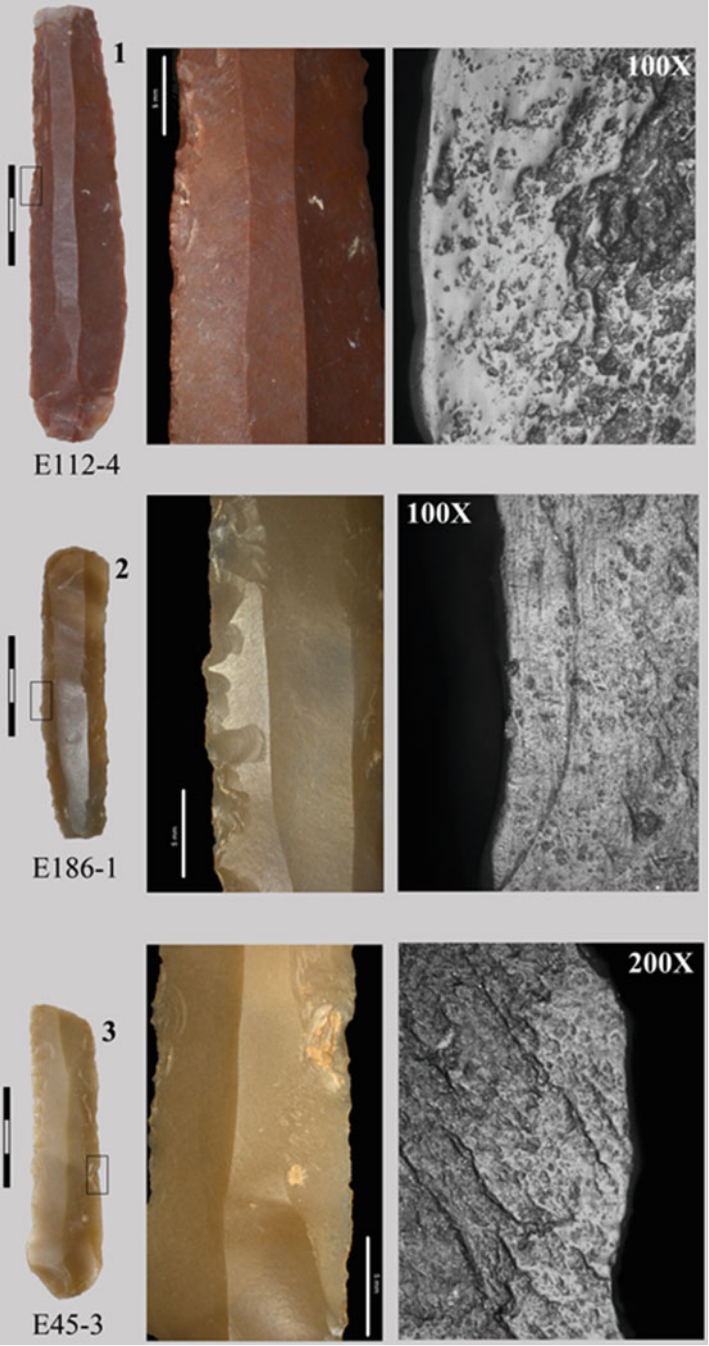

Fig. 13.4 Sickle elements from Can Gambús (Catalonia, Spain), corresponding to sickles with flint blades in parallel insertion

Fig. 13.5 Wooden sickle from the waterlogged site of La Draga (Banyoles, Girona, NE Spain) with one flint blade in parallel insertion (Bosch et al. 2006)

a deeper cutting of the bundle of cereal stems, because of its oblique angle of attack, though the insertion is more fragile, as the blade is more exposed (it is only fitted into the shaft by one extremity) so it can be more easily broken or unhafted.

One complete sickle of this type, in which a broken flint blade is still inserted obliquely to the shaft, has been found in La Draga (Bosch et al. 2006; Palomo et al. 2011; Fig. 13.5). Another sickle made of antler, which was found in the Neolithic site of Costamar, in Castellón, also corresponds to this type. It was made from a fragment of deer antler, consisting of a main straight shaft and a lateral branch. In the main shaft a deep and short incision is the place where the flint blade must have been inserted obliquely (Flors et al. 2012).

Flint insertions in this category of sickle are long blades (from 5 to 8 cm) which display a gloss distribution occupying two-thirds to one-half of the cutting edge, being more marginal at the proximal end and getting more invasive towards one of the extremities. In this extremity the use-wear polish can be very invasive, up to 1 cm or more. The distribution of the gloss shows that the blade was inserted in the shaft obliquely (Fig. 13.6).

Sickles of La Draga 1 and 2 types were used in the same way, with a two-stage harvesting action (gathering and cutting), and only vary in the position of the flint blade insertion (either parallel or oblique to the shaft). In some of the sites where Type 2 has been found, it is accompanied by the Type 1 (La Draga, La Vaquera, Grotte Lombard, Petites Bâties, Basi). There is a noticeable geographical and chronological overlapping in the use of both types of sickles and consequently they are thought to be simply technical variants of the same type.

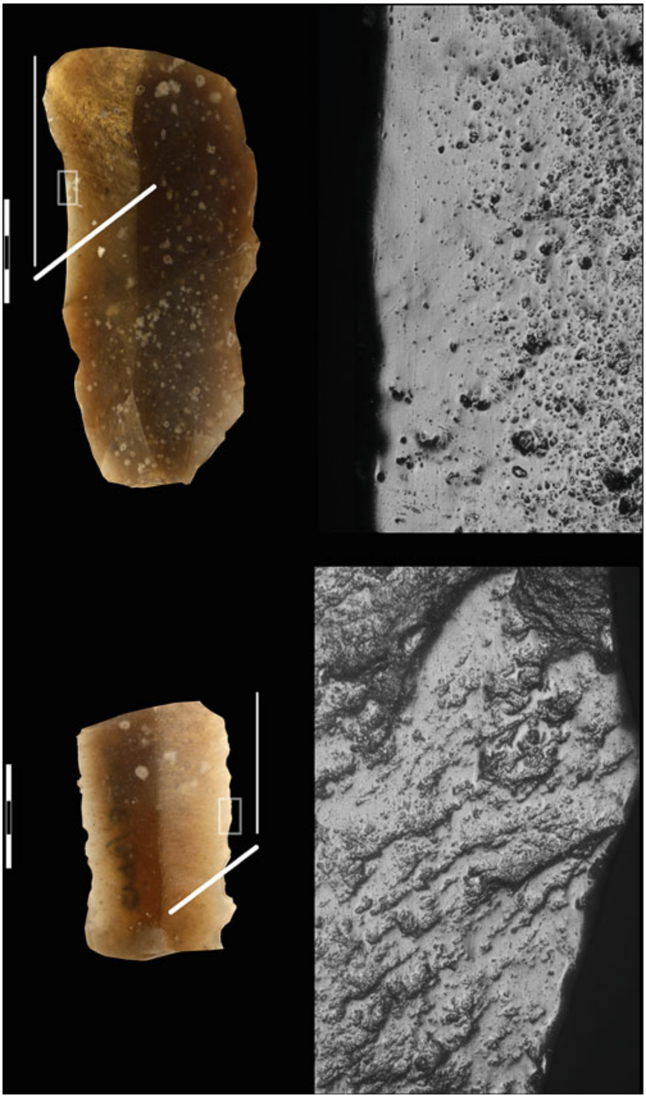

Fig. 13.6 Sickle elements from La Vaquera (Castile, Spain) corresponding to sickles with one flint blade in oblique insertion

13.3.3.1 Abrasive Traces

Under the incident light microscope, sickle gloss is observed as a highly reflective and regular surface, where multiple slight striations show the direction of the movement of the tool (Fig. 13.7a). However, some of the glossed tools in the area of study show a much more abrasive microwear polish. In some of the tools, typical

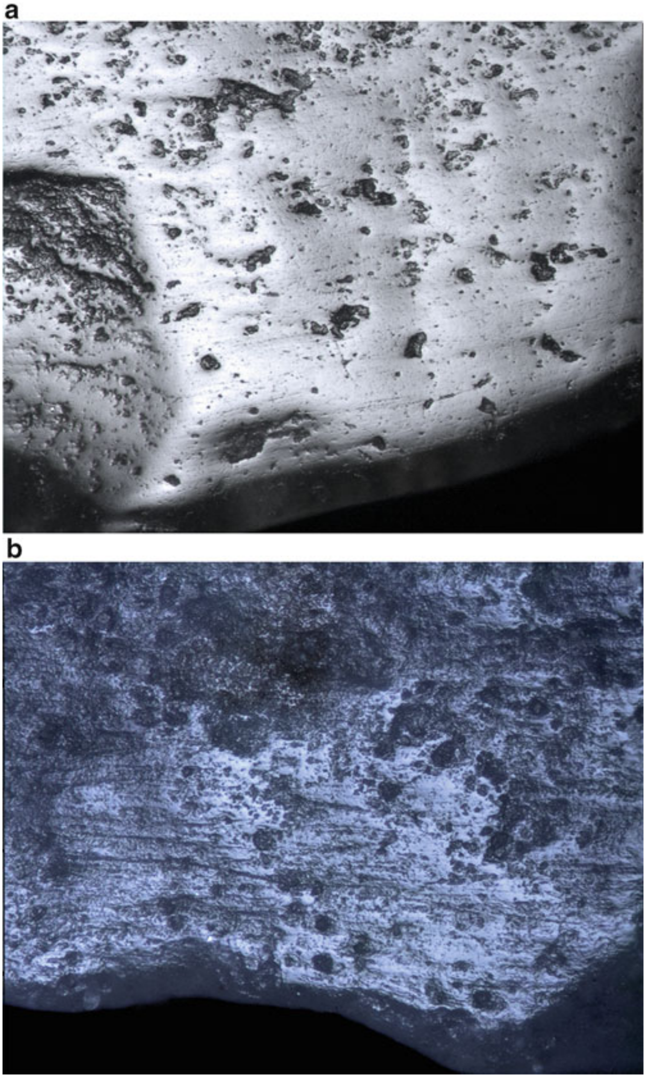

Fig. 13.7 Microwear traces from the site of Los Cascajos. (**a**) Typical cereal harvesting traces. (**b**) Harvesting traces which were abraded by a second use of the tool, most probably from cutting cereal stems on the ground

cereal harvesting microwear polish is intensively abraded, indicating that sickle elements were later reused in other activities which caused the abrasive traces (Fig. 13.7b). In other tools, only the abrasive traces are present, suggesting that unused blades were employed in the activity generating abrasive traces. Our experiments have shown that these abrasive traces are generated when the stems of the cereal are cut on the ground, and the abrasive particles in the soil cause the abrasion of the surface (Clemente and Gibaja 1998). Most probably the cereal stems were cut in this way in order to separate the ears which could be later stored while the stems could be used as fodder or as bedding for the livestock.

13.3.3.2 Geographical Distribution

La Marmotta sickles are found at many sites in Andalusia (Murciélagos de Albuñol, Murciélagos de Zuheros, Castillejos de Montefrío, Bajondillo, Nerja), Valencia (Cova del Or, Barranquet, Cova de la Sarsa, Mas d'Is), central and southern coasts of Portugal (Cortiçois, Vale Pincel I), Peninsular Italy (Torre Sabea, Trasano, Cialdino, Fornace Cappuccini), and some sites in Liguria (Level 15 in Arene Candide), Provence (Fontbregoua, Baratin), Languedoc (Peiro Signado), Catalonia (Guixeres de Vilobi), and Navarre (6th millennium level in Los Cascajos).

La Draga-type sickles are observed in the central (Casa Montero, La Vaquera) and NE (La Lámpara, La Revilla, 5th millennium level in Los Cascajos) Iberian Peninsula, Catalonia (La Draga, Sant Pau del Camp, Cova del Frare, Mine 16 at Gavà, Bòvila Madurell, Plansallosa), Castellón (Costamar), Languedoc (Mas Vignolles), Provence (cardial2 levels of Pendimoun, Petites Bâties, Grotte Lombard, Fontbregoua, Baratin), Liguria (VBQ levels in Arene Candide), Corsica (Strette, Basi), the Po Valley (Isorella, Pizo di Bodio), and the Friuli region (Sammardenchia, Piancada). Thus, there is a relative geographical coherence in the distribution of both types of sickles, with the La Draga sickles related to the North of the Western Mediterranean and La Marmotta sickles to the center and south, though the former are also present at some sites in the north, as at Peiro Signado, Guixeres the Vilobí, Arene Candide, Baratin, and Fontbregoua. In most of the sites, either one type of sickle or the other was used. Archaeological sites where both La Marmotta and La Draga sickles are present are few. In southern Italy, the Marmotta-type sickle is dominant, but in two sites, La Starza and Trasano, some elements with parallel insertions were also documented (Table 13.1) and this is possibly also the case in Ripa Tetta (Petrinelli Pannocchia 2007). In the cardial levels of Fontbregoua and Baratin, in Provence, both types of sickles are also present. In two sites, Los Cascajos and Arene Candide, both types of sickles have been observed but in both cases their use was not contemporaneous, with La Marmotta sickles used in the older levels while La Draga sickles are associated with a more recent occupation of the site. The presence of some glossed tools with abrasive traces, probably caused by cutting the cereal stems on the ground after harvesting in order to separate the ears from the straw, is clearly associated with the sites where La Draga-type sickles are present, while these traces are absent from the sites with La Marmotta-type sickles (Table 13.1).

13.4 Discussion

The variability in harvesting techniques can be explained by several factors. It can be the result of the adaptation of harvesting techniques to the climatic or pedological characteristics of a region or it can be related to the characteristics of the cereal being harvested. However, the variability in the characteristics of the sickles seen above does not seem to be explained by these variables. These are all regions with a Mediterranean climate with a greater or lesser continental influence. Both types of sickles were sometimes used in the same region, while the same type of sickle is present in areas showing some climatic variability. Moreover, previous studies have shown that there is no direct relationship between the types of sickle in use, the region, and the kind of cereal being cultivated (Gassin et al. 2010). Because of this, we believe that the distribution of the two types of sickles reflects technical choices related to two different cultural traditions.

Agriculture is a complex and risky productive process. Cultivation implies the deployment of complex knowledge integrating variables related to the biology of the plants, climate, and soil characteristics. Any wrong decision taken dealing with all these variables can result in a spoilt crop. This complexity and risk imply that the transmission of agriculture needs to be carried out in a context of direct and long contact between trainers and trainees (Perlès 2012). This can take place in the context of intergenerational sharing of agricultural experiences inside farming communities, or, in a second scenario, in a context of durable and direct contact and interaction between groups of farmers and hunter-gatherers. The relatively quick transmission of the Neolithic in the Western Mediterranean indicates that agriculture spread by colonizing groups. This does not mean that acculturation did not exist, but this would have happened in a second stage when stable interaction between the Neolithic newcomers and the indigenous hunter-gatherers was possible (sensu dual model). Acculturated ex-hunter-gatherers genetically mixed with original farming groups would have shared the strategy of expansion of Neolithic communities. Through the acculturation process, the agricultural know-how (including sickle types) would have been transmitted to the new farmers. Because of this, in either colonization or acculturation scenarios, the geographical distribution of sickle types during the Early Neolithic was the result of the expansion of agriculture. The transmission of technical variants between groups sharing similar technical systems is easier and can take place during a short lapse of time (Raynaut 1984). Thus, once agriculture has been adopted by neighboring groups, technical transfer between them is easier.

We need to collect more data on the distribution of sickles in time and space to trace the paths of this spread. However, our current data permit us to propose some preliminary hypotheses. If we consider our data on the geographical distribution of sickle types on the chronological axis, this distribution gains in coherence (Fig. 13.8). The first farming communities settling in southern Italy used La Mamotta-type sickles from the beginning of the 6th millennium. In some sites, parallel-inserted elements were also in use beside the multiple oblique ones

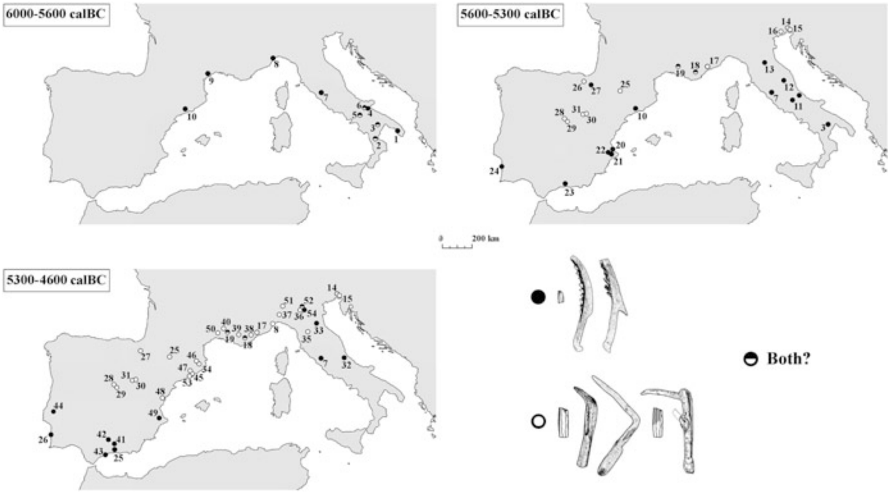

Fig. 13.8 Map with the archaeological sites and the sickle type in three successive chronological periods. *1*, Torre Sabea; *2*, Favella della Corte; *3*, Trasano; *4*, Coppa Nevigata; *5*, La Starza; *6*, Ripa Tetta; *7*, La Marmotta; *8*, Arene Candide; *9*, Peiro Signado; *10*, Guixeres de Vilobí; *11*, Santo Stefano de Ortucchio; *12*, Maddalena di Muccia; *13*, Cialdino; *14*, Sammardenchia; *15*, Piancada; *16*, Vlaer; *17*, Abri Pendimoun; *18*, Fontbrégoua; *19*, Le Baratin; *20*, El Barranquet; *21*, Mas d'Is; *22*, Cova Sarsa; *23*, Cueva Nerja; *24*, Vale Pincel I; *25*, Cueva de Chaves; *26*, Atxoste; *27*, Los Cascajos; *28*, La Vaquera; *29*, Casa Montero; *30*, La Revilla; *31*, La Lámpara; *32*, Colle Cera; *33*, Fornace Cappuccini; *34*, La Draga; *35*, Mileto; *36*, Isorella; *37*, Brignano Frascata; *38*, Grotte Lombard; *39*, Mourre de la Barque; *40*, Petites Bâties; *41*, Case Montefrío; *42*, Murcielagos de Zuheros; *43*, Bajondillo; *44*, Cortiçois; *45*, San Pau del Camp; *46*, Plansallosa; *47*, Cova del Frare; *48*, Costamar; *49*, Cova de l'Or; *50*, Mas de Vignoles; *51*, Pizzo di Bodio; *52*, Ostiano Dugali; *53*, Minas de Gavà; *54*, Campo Ceresole-Vhò di Piadena. Vale Pincel I, Cueva del Toro. Murciélagos de Albuñol

(La Starza, Trasano). The analysis carried out in Franchti (Tesalie, Greece; Gassin) has shown that both types of sickles were in use, although those with parallel insertions are more numerous. These data suggest that the first farming communities coming from Greece would have been using both types of sickles, though La Marmotta sickles were more commonly employed.

In central Italy, during the first half of the 6th millennium, only La Marmotta-type sickles have been documented. As it is well established that this area was populated by Neolithic groups arriving from southern Italy, these data indicate that farming groups in S. Italy would have re-elaborated their Neolithic package, abandoning the use of sickles with parallel-inserted elements when they started their expansion towards the North.

Short oblique elements are also present in Peiro Signado, while one of these elements with a double use (use of both edges one after the other) was detected in the older Neolithic levels of Arene Candide. Despite the absence of the analysis of sickle elements at other Impressa sites in SE France (Pont de Roc Haute, Caucade, Pendimoun), which might confirm our interpretation, this information seems to suggest that maritime pioneer groups coming from central-southern Italy used La Marmotta sickles. This kind of sickle is also present at the first Neolithic Spanish Levantine sites, at those dating from the end of the first half of the 6th millennium, with Impressa pottery in Valencia (Barranquet, Mas d'Is), Cardial pottery in Catalonia (Guixeres de Vilobí), and also at the site of Nerja (Malaga), where Impressa and Almagra pottery is present. To explain this distribution of La Marmotta sickles in the E and S coasts of Iberia at these early dates, two explanations are possible. The track of the Neolithic maritime expansion documented in SE France would have continued to the South, arriving to the Andalusian coasts. An alternative interpretation for the first Neolithic in south Iberia would imply the arrival of groups with an Italian origin along the North African path. In fact, our data on sickle elements indicate homogeneity in the morphology of sickles used by Neolithic groups distributed along the Mediterranean coast from south Italy to central Portugal in this early period. This information could fit equally well with an exclusively northern expansion (Zilhão 2001) or with a northern expansion complemented with a southern one along the African coasts (Gibaja and Carvalho 2010; Manen et al. 2007; García Borja et al. 2011).

During the mid-6th millennium, for the first time, La Draga-type sickles appear in NE Italy, in the Friuli area (Sammardenchia, Piancada). During the second half of the 6th millennium, these kind of reaping tools are also present in the Ligurian, Provenzal, Languedocian, and Catalan regions, as far as the north of Castellón (Costamar). From 5350 BC, the interior of Iberia is occupied by Neolithic groups (Rojo et al. 2012), using La Draga-type sickles, as documented in the central and northern areas of the Spanish Central Plateau (La Lámpara, La Revilla, La Vaquera, Casa Montero).

Meanwhile, La Marmotta sickles are still present in the Italian Peninsula, as far as the Po valley, and on the southern Levantine Spanish coast and in Andalusia. During the second half of the 6th millennium, the expansion of groups with La Marmotta sickles continued to the coastal areas of Andalusia and south and central Portugal, while some incursions into inland areas of Spain took place, as in Andalusia (Murciélagos de Zuheros, Murciélagos de Albuñol) or, probably, along the Ebro River (early level at Los Cascajos).

By the late 6th millennium–early 5th millennium a more stable picture is defined for the distribution of sickles in the Western Mediterranean, with La Marmotta sickles being used in the southern part of Iberia and in the Italian Peninsula and La Draga sickles occupying continental Italy, the Gulf of Lyon, and the northern half of Iberia. Once established, the two cereal harvesting technical traditions coexisted for over a millennium.

As seen above, from the mid-6th millennium, Neolithic groups using La Draga sickles appeared, first in NE Italy and soon afterwards in the Ligurian-Provenzal-Languedocian-Catalonian arc and in the inner Iberian Peninsula, bringing a well-developed system of farming economy (Zapata et al. 2004; Rottoli and Castiglioni 2009; Antolín et al. 2014). Neolithic groups with this type of sickle brought the new way of life for the first time into some areas of N Italy and the Iberian Peninsula, such as in the central and northern plateau, while they were also present in areas which had been previously occupied by groups with Impressa and Cardial pottery, in Liguria, Provence, Languedoc, and Catalonia. By the end of the 6th millennium the new agricultural technical tradition seems to have substituted the previous one, with La Marmotta sickles replaced by La Draga ones in the northern half of Iberia, the Gulf of Lyon, and continental Italy.

The appearance of this new technical tradition implying the use of La Draga sickles and the cutting of the stems on the ground (abrasive traces in some glossed tools) could be explained by the acculturation of local populations in contact with the first farming communities (Cardial groups) during the second half of the 6th millennium. However, although this hypothesis cannot be ruled out in the current state of our research, we believe that it displays some inconsistencies. First, it is difficult to explain why acculturated local communities would have adopted a type of sickle which is different from the one used by their "teachers." Second, if local communities played an active role in the incorporation of agricultural techniques, it is not easy to understand the extended and homogeneous use of the same type of sickle from NE Italy to the center of Iberia. Third, the older farming groups using La Draga sickles (Samardenchia, Piancada, La Draga, La Vaquera) possessed a well-developed farming economy, while a more progressive adoption of the new economic system would be expected in an acculturation model. On the contrary, the distribution and chronology of events in the appearance of La Draga sickles, with an east-to-west chronological gradient and a widespread geographical distribution, suggest that a new wave of Neolithic expansion with farmers bearing a new agricultural technical tradition could have taken place, by a mostly terrestrial way, from NE Italy to southern France and the interior of the Iberian Peninsula.

This hypothesis of two waves of Neolithic expansion in the Western Mediterranean, the first one mainly maritime from the south-central Italy and the second one mainly terrestrial, can be supported by data related to the exploitation of animal and plant resources. J.D. Vigne has noticed some differences in the characteristics of the sheep which were brought by the first Impressa pottery pioneer groups in southern France during the first half of the 6th millennium and the sheep which were kept by the later Cardial groups during the second half of the 6th millennium. Sheep at the Impressa sites are more robust than the later ones and their horns are hollow in contrast with the solid ones at the Cardial sites. Sheep at Impressa sites are similar to those observed in central Italy and to the current Corsican-Sardinian mouflon which are original Neolithic sheep turned wild. Because of this, this scholar proposes a different origin for the sheep of Impressa farmers, in the first half of the 6th millennium, which were brought to southern France from central Italy, while the lighter Cardial sheep could have had a Balkan origin, arriving through northern Italy (Vigne 2007). Moreover, this double origin of the Western Mediterranean Neolithic could explain the presence of two divergent mtDNA lineages of goats at the Early Neolithic site of Baume d'Oullen (Ardèche, SE France; Fernández et al. 2006).

Archaeobotanical data from the Friuli region would also support this hypothesis. As Rottoli and Castiglioni (2009) state, the influence of the Danilo culture, from the north-western part of the Balkans, in the Friuli area, and the contacts of this area with southeastern Europe are evidenced by the presence of the "new glume wheat," which is now well known in Greece and eastern Europe during the Early Neolithic (Jones et al. 2000; Marinova and Valamoti 2014). Interestingly, this kind of wheat has also been identified in the early phase (5300–5200 BC) at La Draga (Antolín et al. 2014). Moreover, the low importance of contacts of the Friuli area with southern Italy is confirmed by the scarcity of free-threshing wheat (Rottoli 2014), which is mainly distributed in the Mediterranean area (Costantini 2002), and the absence of poppy, which was cultivated at La Marmotta (Rottoli 1993). At the same time, the rich archaeobotanical spectrum in the Friuli area also contrasts with the Linearbandkeramik zone, where only five plant species are cultivated (Rottoli and Castiglioni 2009).

When would this possible expansion of farming groups along the North Mediterranean have taken place? The Neolithic occupation of the Trieste and Friuli area by groups using La Draga-type sickles during the mid-6th millennium would indicate the start of the process. The spread of Neolithic groups with the same type of sickles in the central plateau of the Iberian Peninsula around 5350 would mark an end point. We could therefore be facing a short and quick process of expansion lasting no more than 200 years. The rhythm of this expansion in Provence, Languedoc, and Catalonia is more difficult to establish. Sickle elements from more Early Neolithic sites between 5500 and 5000 BC in this area should be analyzed before reaching a conclusion. La Draga sickles are present at Neolithic sites in this area around 5300 (cardial levels at Pendimoun, Baratin, and Fontbregoua), but taking account that some short oblique elements are also present in Fontbregoua and Baratin, we suggest that the process of substitution of La Marmotta sickles by La Draga ones could have taken place at that moment. In this way, a technical transfer affecting the type of sickle, from the groups bringing the new technical tradition (La Draga type) to the farming groups already established in the coastal areas, which had been using La Marmotta-type sickles, would have taken place, in the coastal arc from Castellón (Spain) to Ligurie. In our hypothesis, three major cultural process could be related with this terrestrial wave of Neolithic expansion: (1) the first Neolithic occupation of continental Italy around 5500 BC, important cultural shifts among Neolithic communities in the Gulf of Lyon area (Ligurie, Provence, Languedoc, Catalonia) taking place around 5300 BC, and the Neolithic occupation of inner Iberia in a similar chronology.

In NE Italy, the large open-air settlements of Sammardenchia and Piancada (both sites with La Draga sickles) have produced large assemblages of cultivated crops in the mid-6th millennium (Rottoli and Castiglioni 2009). The neolithization of this area, the Trieste and the Friuli regions, has been culturally related to the Balkan Neolithic. In fact, the Impressed ware which extended towards the north along the Adriatic coasts during the 6th millennium never reached the head of the Adriatic. The Danilo culture from the Balkans represents the first Neolithic at Pupićina (Istria Peninsula, Croatia), at ca. 5600 cal BC (Forenbaher and Miracle 2006). The first Neolithic in the Trieste Karst is represented by pottery of the so-called Vlaška group, of eastern filiation (Barfield 1972; Bonsall et al. 2013), starting in the mid-6th millennium. Thus, the Balkan filiation of the Neolithic groups settling in NE Italy can be reasonably argued (Pessina and Tiné 2008; Pessina and Muscio 2000; Grifoni Cremonesi 2012). Bearing this in mind and the fact that Samardenchia is the oldest site where the use of La Draga sickles has been documented, we can hypothesize a Balkan origin for this wave. Further west, the Fiorano Culture, in the Po Valley, first dated in the mid-6th millennium (Improta and Pessina 1998), where Lugo di Romagna and Lugo di Grezzana yielded small sickle elements inserted obliquely, is interpreted as a local elaboration from a mixture of northern and southern influences (Rottoli 2014).

In the Gulf of Lyon, an abrupt cultural transition takes place around 5300, with the appearance of Epicardial groups, which for around 400 years are contemporaneous with the Cardial ones both in France and in Spain (van Willigen 1999 2004; Bernabeu 2006; Manen et al. 2010). At the same time, some changes taking place in the Cardial groups gave rise to a recent phase of this technocomplex (Manen 2000). This Late Cardial phase is characterized by important changes in the techniques of pottery making (appearance of the coiling technique), in pottery decoration (Echallier and Courtin 1994; Binder 1991), and in the strategies of livestock exploitation, with a wider spectrum of domestic animals (including goats and cattle), which has led some scholars to suggest the possibility of the existence of a second wave of Neolithic expansion in the mid-6th millennium (Binder et al. 2008), coinciding with an episode of climatic deterioration (Berger 2005).

The interior areas of the Iberian Peninsula begin to be populated by Neolithic groups around 5350 BC (Rojo et al. 2008; Estremera 2005), who brought with them a well-developed agro-pastoral package (Zapata et al. 2004). This inland Neolithic has been explained as the result of the acculturation of local communities in contact with Neolithic groups from the Levantine coast (Bernabeu and Martí 2014). However, there are no traces of the hypothesized Neolithic groups with Cardial or Impressa potteries before 5350 BC in the interior areas of Iberia. Some of the sites analyzed in this area possess La Draga sickles (Casa Montero, La Vaquera, La Lámpara, La Revilla, the later level at Los Cascajos) while short elements with oblique insertion (La Marmotta-type sickle) are present in the early levels at Los Cascajos. In our hypothesis, most of the first Neolithic groups in the center of the Iberian Peninsula could be part of the western extremity of a terrestrial wave of expansion of farming communities, of which Neolithic groups with La Draga sickles in the Gulf of Lyon and N Italy were other manifestations. However, as the early level at Los Cascajos shows, this Neolithic spread in inland Iberian Peninsula was probably more complex, as Neolithic groups with La Marmotta-type sickles, probably coming from the Levantine coast, were also expanding into the interior of Iberia.

13.5 Conclusions

Despite considerable advances being made in recent decades, the paths and rhythms of Neolithic expansion from the Near East into Europe are still poorly understood. This topic has traditionally been studied by resorting mainly to the study of pottery styles and C14 dates. However, pottery style, and more specifically decoration, is a very dynamic cultural item, which can shift quickly. Pottery styles are very sensitive to cultural change, so its analysis is especially adequate for detecting short-term changes, expansions, and interactions of human groups. Because of this, in order to tackle a long-term process, such as the Neolithic expansion, the exploration of more conservative cultural aspects, like those associated with the strategies of resource acquisition, can provide useful data.

Ethnoarchaeological information shows that harvesting technology is varied and very conservative, and can be expected to be transmitted unaltered through intergenerational or acculturation learning as part of agricultural technology. The analysis of harvesting technology at some Early Neolithic sites in the Western Mediterranean has shown that two main types of sickles were used by farmers: what we call La Marmotta-type sickle, a curved shaft where flint elements were inserted at an oblique angle, which was used in the same way as contemporaneous ethnographic sickles in, for example, the Mediterranean area, and what we call La Draga sickles, with an L-shaped shaft, where the lateral branch was used for gathering the stems which were held in the bare hand and cut off with a flint blade inserted in the main shaft of the sickle. Two variants of the La Draga-type sickle are represented by tools in which the flint blade was inserted parallel to the shaft, which are more numerous and those where the flint blade was inserted obliquely. Moreover, in the sites where La Draga sickles were used, some glossed blades with abrasive microwear polish have been detected and interpreted as the result of cutting the cereal stems on the ground, probably to separate the ear from the straw, in order to store the former and use the latter. Users of both types of sickles were resorting to two different technical agricultural traditions.

The geographical distribution of both types of sickles shows some patterns, with the La Draga sickles being present in the North of the Western Mediterranean and La Marmotta sickles in the center and south, although the latter are also present at some sites in the north, as at Peiro Signado, Guixeres de Vilobí, and Arene Candide. With the data currently at our disposal and taking into account the chronology of the appearance of the sickle types in the archaeological sites, a coherent scenario for the Neolithic expansion can begin to be traced. The first farming communities settling in southern Italy used mainly La Marmotta-type sickles and some others with flint elements inserted parallel to the shaft at the beginning of the 6th millennium. These groups expanded to the north (central Italy, Corsica, and Sardinia, some early sites in the Gulf of Lyon and in the Spanish Levantine coast) with La Marmotta-type sickles and Impressa pottery during the first half of the 6th millennium. By the mid 6th millennium, Neolithic communities using La Marmotta sickles were present in the Western Mediterranean coasts as far as Andalusia. At the same time, some Neolithic groups with La Draga sickles appear in NE Italy (Friuli area). During the following centuries, in the second half of the 6th millennium, La Draga sickles began to be used in Ligurie, Provence, Languedoc, and Catalonia, substituting La Marmotta-type sickles, and it is also the type brought by the first farmers populating the central and northern Iberian Plateau. At the same time, Neolithic groups with La Marmotta sickles also expanded to inner Iberia.

The expansion of Neolithic communities with La Marmotta-type sickles can be explained in the framework of the theory of the maritime pioneer groups (Zilhao 2001), and may have involved either an exclusive expansion from the northern Mediterranean or a second and complementary path along the North African coasts. However, how can we explain the appearance of the technical tradition associated with the use of La Draga sickles and the presence of abrasive traces in some glossed tools? We think that the most plausible hypothesis, which should be confirmed in further studies, is that this technical tradition shows the existence of a terrestrial wave of expansion of Neolithic farmers starting in the mid-6th millennium in NE Italy and spreading rapidly (in no more than 200 years) as far as the center of Iberia. If this is the case, that means that a third wave of Neolithic expansion (with La Draga sickles, probably originating from the Balkan Peninsula) would have been geographically intermediate between the Linearbandkeramik wave (associated with Karanovo sickles), in the north, and the maritime pioneers in the south (associated with La Marmotta sickles). Nevertheless, we are aware that more data are still needed to be able to confirm this hypothesis which, however, we think is the most plausible explanation for the current data in a research project which is still in progress.

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Chapter 14

Spatial and Temporal Diversity During the Neolithic Spread in the Western Mediterranean: The First Pottery Productions

Joan Bernabeu Aubán, Claire Manen, and Salvador Pardo-Gordó

14.1 Introduction

The transformation of subsistence systems from hunting and gathering to farming involved a crucial change in the relationship between humans and the environment, which affected all levels of human society. Perhaps for this reason, the issue of the origin and spread of Neolithic economies remains a major topic in archaeological and anthropological literature. This is certainly the case regarding Europe, where the subject of the origin of farming societies is fundamentally concerned with the nature of their dissemination.

Current archaeological data suggests two primary routes taken by the spread of agriculture in Europe: along the Danube River corridor from the Balkans to the North Sea, and around the Mediterranean littoral (Guilaine 2001). To date, most efforts to understand the Neolithic spread have been made on a continental scale, using the dates (radiocarbon data) and places (first Neolithic sites) as the key variables to evaluate the viability of a demic expansion. The quantity of information concerning the Western Mediterranean in these studies has been rather sparse (but see Isern et al. 2014). Moreover, cultural information has been rarely used.

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If, as is commonly assumed, the Neolithic expansion was essentially due to a process of demic diffusion, then it can be assumed that this process had some effect on the variability of cultural items over time and space. We can expect that during the expansion there was a continuous development of knowledge and styles, so that overall the Western Mediterranean should show a certain degree of polymorphism in the pottery productions (Bernabeu Aubán et al. 2011; Manen et al. 2014). With regard to decoration, the main feature used to follow the rules of diffusion of the Neolithic in the Mediterranean, it is necessary to understand the process that led to the potters making changes in the way in which the ceramics were decorated, and eventually led to the kind of ceramic assemblages that we see in the archaeological record. In our opinion, the evolutionary theory could be helpful in this regard.

The introduction of the theory of cultural evolution into archaeology during the 1980s has provided the basis for a new approach to understanding the processes that produced temporal and spatial variation in the past. This has been done by focusing on the transmission of information, and the factors acting on the variation that is transmitted (see, e.g., Eerkens and Lipo 2007), as well as the mechanisms by which any innovation becomes diffused among a given population (O'Brien and Bentley 2011). The extent to which human culture varies over space and time is determined by a complex interplay between patterns of inheritance, interaction, and adaptation (Mace and Jordan 2011; Crema 2014). Distinguishing how these three types of processes generate observable patterns of cultural variation is one of the primary research questions in archaeology and anthropology. Although there are a growing number of studies of individual technological traditions, such as textiles, basketry, and clothing in ethnohistoric studies, and projectile points and pottery in archaeological studies (see Jordan and Shennan 2009 and references on p. 343), investigations aimed at understanding the possible relationship between the specific direction of the Neolithic spread, and the spatial diversity of "cultural" makers, are less frequent.

With regard to Europe, this kind of information has been included in attempts to understand the effect of some evolutionary processes in the spatial distribution of crop diversity (Conolly et al. 2008; Pérez-Losada and Fort 2011); but the patterns of spatial diversity in cultivated plants are frequently affected by environmental conditions, which downplays its usefulness to evaluate hypotheses concerning the effects of the Neolithic spread in the spatial patterns of cultural diversity. In this chapter we focus on the use of pottery decoration as a way to investigate the mechanisms of the Neolithic spread in the Western Mediterranean.

More specifically, our intention is to explore the viability of the hitchhiking hypothesis. To do that we assume a demic diffusion model so that "Demic flow raises the possibility that cultural, genetic and linguistic traits with no intrinsic advantage may "hitchhike," i.e., spread with the advancing farmers" (Ackland et al. 2007, p. 8714). Any trait that preexists alongside the advantageous one could be carried along with it, regardless of any intrinsic superiority. The separation of the advantageous trait from other "hitchhiking" traits depends on various possibilities, such as its adoption by the preexisting population, or, more simply, if demic diffusion is not the primary driver of the spread. In the next sections we present the archaeological background of early pottery styles in West Mediterranean and their radiocarbon chronology; then we present the methodology we used to analyze the diversity of these pottery productions; and in the last section we present the results and discuss which are the processes behind the observed diversity.

14.2 The Western Mediterranean

The Western Mediterranean, extending from southern Italy to Portugal and northern Africa, can be considered a single archaeological unit where diagnostic features of Early Neolithic contexts share a number of common elements, exemplified by the pan-regional presence of Cardium-Impressed ceramic wares. Some consensus exists regarding the origin of these wares in southern Italy, but the debate surrounding its process of expansion to the west remains open. Perhaps, as noted by Zeder, the processes responsible for the expansion of agricultural systems "... involved elements of demic diffusion, local adoption, and independent domestication" (Zeder 2008, p. 11603); but the cultural contexts of this dispersal, its routes, and its tempo have not yet been adequately resolved (Manen 2014).

It is commonly accepted that the first pottery productions of West Mediterranean appear in southern Italy around 6000 cal. BC. Known as Impressed Ware ceramics, the question of their origin or their links with the East remain largely unknown, mainly due to the lack of data in the intermediate Aegean region and the scarcity of impressed ware in the oldest periods. But recent and audited findings at Sídari (Corfú, Greece) show that an archaeological layer with impressed ware dated on 7170 ± 40 succeeds one with monochrome pottery around 6000 cal BC (Berger et al. 2014, p. 223).

In southern Italy, this impressed pottery is classified into two classes (Guilaine and Cremonesi 2003; Natali 2010; Radi 2010): coarse and fine. Big pots with abundant temper and thick walls characterize coarse pottery. Decorations are made with impressions, using a wide range of instruments: shells of notched or plain edges, fingers, flint flakes, pointed tools, and others. These impressions are not organized in a geometric way and cover the whole surface. Fine pottery is associated with medium and small pots, of thin walls, with few temper inclusions. Decoration is less frequent in this category using the same tools but in a different way: the "microrocker" or the "sequenza" techniques are found here (Natali 2010). Over time, the decorations tend to be organized in geometric themes while the techniques used seem to be more and more diversified.

Therefore, these Impressa pottery productions constitute the background to which the pottery production of the whole Mediterranean area is partly related. From this perspective we will present a short overview of the early stages of the regional Neolithic ceramics. For our purposes it is not so important whether or not the early phases qualify as Impressa (e.g., if the technical system makes specific reference to the impressed ware). What we are seeking to discover is a clear spatial pattern that could be related to an expansion from southern Italy, the supposed center of origin of the West Mediterranean Neolithic. For this reason the term "impressa phase" is used here in a chronological sense, as a way to easily characterize the very first pottery production of each Mediterranean region.

14.2.1 The Tyrrhenian Area and Southern France

At the same time that southern Italy Neolithic evolves and expands, it seems that small groups of pioneers start moving to the west from 5800/5700 cal BC. Their remains can be identified in some sites of central and northern Italy, as well as in Corsica and on the French coast of Provence and Languedoc (Guilaine et al. 2007), and probably reaching the Spanish shoreline (Bernabeu Aubán et al. 2009). Of course, it is probable that some people move west along the southern route, via Sicily and northern Africa. This introduces the African expansion route into the current debate of West Mediterranean Neolithic spread (Manen et al. 2007; García Borja et al. 2010; Cortés Sánchez et al. 2012; Linstädter et al. 2012). But apart from some Sicilian sites (Tiné 2002), information from North African early Neolithic is a long way from contributing conclusive information on this subject. For this reason we limit ourselves to the north-occidental west Mediterranean arc.

In the ligurian-Provençal arc, we can see the remains of these pioneer groups in the relics found in sites like Arene Candide (Binder and Maggi 2001), around 5800/5700 cal BC. The ceramic production of this site is decorated with the «sillon d'impressions» technique. Other sites, like Pendimoun o Caucade, could be related to this period. At Pendimoun (Binder and Sénépart 2010), we see these first Neolithic groups practicing a mixed agricultural system with the presence of wheat and barley, combining with pastoral activities based on sheep. Ceramic production at these sites could be connected with the Italian impressed wares, but some differences are evidenced between them. In Corsica, this first horizon has been recently identified at Campu Stephanu (Cesari et al. 2014), showing a pottery production dominated by single cardial impressions very close to that present at the Isola dei Giglio in Tuscany (Brandaglia 1991).

Two other sites, located to the west of the Rhone valley, could be related to these pioneering groups: Peiro Signado and Pont de Roque-Haute (Guilaine et al. 2007; Briois and Manen 2009). With a consolidated agro-pastoral economy, the ceramic productions of these neighbor sites show some differences between them, so that Peiro Signado seems closer to Arene Candide while Roque-Haute resembles the Tyrrhenian sites of Giglio and Campo Stephanu. Nonetheless the presence of obsidian tools, from Sardinia, Lipari, and Palmarola (Briois et al. 2009), reinforces the links between all these sites.

14.2.2 The New Dates of Spain and Portugal

In the last few years, new discoveries in the Iberian Mediterranean coast outline the presence of this same kind of pottery production related to the "impressa phase." In general, the sites of the Iberian Peninsula contain few assemblages, and this includes ceramics. For this reason, information on other aspects of material culture or economic activities is also more scarce than in other regions. The best known area is the Cap Nao region, on the central Mediterranean coast. In this area, between the current provinces of Alicante and Valencia, we know of three sites that clearly present layers associated with impressa: Barranquet (Bernabeu Aubán et al. 2009), Mas d'Is (Bernabeu Aubán et al. 2003), and En Pardo cave Layer VIIIb (Soler Díaz et al. 2013). We have five radiocarbon dates for these sites, ranging from 5650 to 5450 cal BC. Although we know of the presence of domestic taxa in all these sites the information is still very scarce.

Decoration techniques exhibit similar traits with those of the Tyrrhenian area (the use of sillons d'impression, known as *boquique* in Iberia) and, of course, some differences. One of the most striking differences between this area and the Tyrrhenian/Southern France is the absence here, and in all Iberia, of any obsidian tool. Once again, the pottery assemblages of El Barranquet and Mas d'Is, two neighboring and more or less contemporary sites, show variations in their decorative patterns.

Although there are other Iberian regions that could be connected with this expansion process, they all have certain difficulties that advise caution in handling their information. Some of them are cave layers with radiocarbon dates that indicate a long depositional episode, so that they could be a mixed collection from different phases. This could be the case at Chaves Ib, Guixeres A, and Cendres H19. For this reason we have decided not to include the pottery samples of these sites in our work.

In the Ebro valley five sites could be related to an early ceramic phase: Forcas II, layers V/VI (Utrilla and Mazo 2014); Peña Larga IV (Fernández Eraso 2012); Balma Margineda (Guilaine et al. 1995); Abrigo de la Dehesa (García-Martínez de Lagrán 2014); and Mendadia II (Alday Ruiz et al. 2012). The first of these present high radiocarbon dates around 5700 cal BC, obtained from short-lived samples. The same is true of Balma Margineda but in this case with dates obtained from charcoal. The relationship between the pottery styles of Abrigo de la Dehesa and Mendandia and the impressa phase is far from clear. The first has been dated at 7013 ± 38 BP (5990–5800 cal BC, a charcoal sample), and the Mendandia layer II at 6540 ± 70 BP (5625–5370 cal BC, bulk of bones). In this latter case, the lower layer III containing the same kind of pottery has been dated at 7265 ± 60 BP (6235–6015 cal. BC, single-bone sample). Except for Peña Larga and Balma Margineda, there are no domestic taxa documented at these sites. And, at least in the case of Forcas and Mendandia, lithic tools are related to the Geometric Mesolithic. In all these sites, ceramics are scarce and have a wider range of decoration techniques. Taking all this into account we will use these sites with caution in our analytical approach (see below). For our analytical work we decided to divide these sites into two regions we name Ebro 1 (Forcas and Margineda) and Ebro 2 (Peña Larga, Mendandia and La Dehesa).

To the south, the information is unclear. Nerja (Málaga) and the Cariguela (Granada) caves are the only two sites that could be associated with the "impressa" phase with radiocarbon dates ranging from c. 5700–5550 cal BC. In the case of Nerja, one date has been made on an *Ovis aries* bone of 6590 ± 40 (5620–5480 cal BC (Aura Tortosa et al. 2013)). Recent radiocarbon dates of the Cariguela caves, made on single-bone samples, place its lower layer (Cariguela 16) at about 6749 ± 39 BP, 5725–5575 cal BC (Medved 2013, p. 217). Both sites have domestic animals, but there is no information about agricultural practices.

In the Atlantic coast of Portugal, there are some possible candidates to be associated with the "impressa phase": in the south, the sites of Cabranosa and Padrao and in the center Pena d'Agua (Carvalho 2008), Almonda cave, Caldeirao (Zilhao 1993), and the new open-air site of Senhora d'Alegria (Valera 2013). Here the first Neolithic stages could be placed around 5450 cal BC, according to the dates of Almonda (Zilhao and Carvalho 2011). Unfortunately it is not possible to know which ceramic remains are associated with this date and, consequently, we decided to exclude this cave. Neither is it clear whether Pena d'Agua and Senhora d'Alegria collections are related to this phase. Here also there is a striking difference from the rest of Iberia: the shape of the geometric tools. Here, segments dominate the pattern while in the rest of Iberia trapeziums are the most popular geometric tools. Consequently, as in the case of the Ebro Valley we will use this data with some caution dividing all these sites into two groups: the Algarve (Cabranosa and Padrao) and the Tagus group (Pena d'Agua, Senhora d'Alegria and Caldeirao).

Summarizing, it seems that, as we move to the west, the first pottery makers of different Mediterranean regions exhibit some degree of variability in their pots. Sometimes this variability has been used to emphasize the non-demic origin of the neolithization process (Díaz del Río 2010; Cruz Berrocal 2012), but for other researchers these same pottery assemblages, or some of them at least, can be seen as a result of a pioneering phase, which has its roots in Southern Italy (Guilaine et al. 2007; Bernabeu Aubán et al. 2009; Zilhão 2011).

This means that we do not have the adequate tools to assess this variability and to evaluate the possibility that all these early assemblages could derive from one central origin, Southern Italy, as a result of some evolutionary process. The first question then is how do we approach this problem. How can we measure the variability? How do we compare geographically (between regions or sites), and how can we interpret the results as a consequence of either process? In the next section we try to characterize the sites associated with the early stage of the Neolithic in different regions and explain the methodology we use to compare them.

14.3 Material and Methods

14.3.1 Decoration Techniques as Cultural Proxy

It is clear that "culture" is a complex concept that includes many different factors. Limiting our focus to those found to be more evident in Neolithic contexts, we can use either lithic or pottery as archaeological proxies of the "Neolithic culture." For our preliminary purposes we are using pottery; and as pottery decoration is one of the classic markers of Early Neolithic, we decided to use "decoration" as an archaeological proxy. Two different decorative aspects may be equally valid for the purposes addressed here: we can use a motif-based approach or a technique-based approach. Finally we decided to use this latter to avoid the problem of fragmentation of ceramics that seriously handicaps the correct reading of the motif.

We proceed from general to particular attributes (Table 14.1). In a general view there are two main ways to make decoration: adding something to the pot (Added), or inscribing the pot surface using a tool (Embedded). Added differs according to the material used, in this case: reliefs and color. Adding color results in three attributes: filled, slip, and painted. Embedded decorations have been differentiated firstly by the way they are made (gesture). We distinguish between simple impression; pivoting; drag; and slab-and-drag.

Then, we consider the tools generally used (notched shells, plain shells, single-edge tool, double- or multiple-edge tool, and fingers). In some cases, we detail the specific tools used (e.g., notched shells can be divided according to the part of the shell used: edge, back, and the umbo; or single-edge tools can be divided according to their footprints: circular, short-line, and others). Out of 46 possible attributes, counting combinations, we have only documented 39, as shown in Table 14.3.

This classification clearly relies on the previous published work (Manen et al. 2010) but with some modifications. This latter makes apparent the difficulties in identifying the tools (e.g., different types of notched shells), in some cases without a direct observation. For that reason we decided to start the upper level of the Embedded decoration by the gestures, which are easier to identify from the publications.

14.3.2 Selecting the Sites

An initial problem arises when trying to compare archaeological assemblages of the first Neolithic: Which ones can be characterized as "the first stages" of the Neolithic? It is clear that the Neolithic commencement varies from region to region. As we are looking to characterize and compare the variability of the first pottery assemblages of the North-Western Mediterranean, including Portugal, we need first to adequately locate those productions in space and time. It is clear that results could be different if we used a large or short temporal window, because of the

Table 14.1 Decorative techniques

Class	Gesture	Instrument level 1	Instrument level 2
A.Embeded	A1. Simple Impression		
		A1a. Notched Shell	
			A1a1. Edge
			A1a2. Back
			A1a3. Umbo
		A1b. Plain Shell	
		A1c. Single Edge Tool	
			A1c1. Circular footprint
			A1c2. Short line
			A1c3. Others
		A1d. Double/Multiple Edge tool	
		A1e. Fingers	
			A1e1. Single
			A1e2. Double
	A2. Pivot		
		A2a. Notched shell	
		A2b. Plain Shell	
	A3. Drag		
		A3a. Notched Shell	
			A3a1. Back
			A3a2. Umbo
		A3b. Single Edge Tool	
			A3b1. Incision
			A3b2. Scratch
	A4. Slag&Drag		
B. Added			
	B1. Clay (reliefs)		
	B2. Color		
		B2a. Painted	
		B2b. Filled	
		B2c. Slip (red/Almagra)	

probable effect of drift alone. As we are primarily interested in the very first stages of Neolithization, we decided to use a temporal window of up to 200 years, after the first pottery appears in each region. Next we describe the procedure used.

The radiocarbon data set used here contains the oldest dates of each region where we have collected information about pottery decorations (Table 14.2). We have selected the dates in accordance with the reliability criteria published elsewhere (Manen and Sabatier 2003; Philippe 2003; Bernabeu Aubán 2006; Zilhão 2011; Manen 2014), using both long- (mainly Charcoal) and short-lived dated samples.

Table 14.2 Radiocarbon data set

Country	Region	Site	Lab Number	Uncal BP	SD	Material		Calibration 1 s		Calibration 2 s		References
Italy	SItaly4	Rendina	LJ 4548	7110	140	Charcoal	LongLifeSample	6205	5810	6330	5715	Cipolloni Sampò et al. (1999)
Italy	SItaly4	Rendina	LJ 4549	6760	100	Charcoal	LongLifeSample	5745	5560	5870	5485	Cipolloni Sampò et al. (1999)
Italy	SItaly4	Rendina	LJ 4550	6670	100	Charcoal	LongLifeSample	5670	5510	5770	5385	Cipolloni Sampò et al. (1999)
Italy	SItaly4	Rendina	LJ 4551	6900	150	Charcoal	LongLifeSample	5975	5665	6060	5540	Cipolloni Sampò et al. (1999)
Italy	SItaly4	Trasano	LY 3896	6810	150	Charcoal	LongLifeSample	5875	5565	5990	5485	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	Ly 4408	6710	180	Charcoal	LongLifeSample	5790	5475	5985	5325	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	Ly 4409	6950	190	Charcoal	LongLifeSample	6005	5670	6220	5530	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	Ly 5300	6940	270	Charcoal	LongLifeSample	6080	5565	6395	5375	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	Ly4410	6830	190	Charcoal	LongLifeSample	5970	5560	6085	5380	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	Ly5296	6950	150	Charcoal	LongLifeSample	5985	5720	6205	5560	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	Ly5297	7030	160	Charcoal	LongLifeSample	6035	5740	6225	5635	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	TAN 88068	6660	150	Charcoal	LongLifeSample	5720	5475	5880	5320	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	TAN88056	6950	140	Charcoal	LongLifeSample	5985	5720	6085	5570	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	TAN88067	6950	130	Charcoal	LongLifeSample	5980	5725	6065	5625	Guilaine and Cremonesi (1996)

(continued)

Table 14.2 (continued)

Country	Region	Site	Lab Number	Uncal BP	SD	Material		Calibration 1 s		Calibration 2 s		References
Italy	SItaly4	Trasano	TAN88248	6980	130	Charcoal	LongLifeSample	5985	5745	6085	5630	Guilaine and Cremonesi (1996)
Italy	SItaly4	Trasano	TAN88313	6790	120	Charcoal	LongLifeSample	5810	5565	5970	5490	Guilaine and Cremonesi (1996)
Italy	SItaly3	Favella	LTL778A	7003	55	Bone	ShortLifeSample	5985	5835	5995	5755	Tinè (2009)
Italy	SItaly3	Favella	LTL202A	6956	75	Seed/Fruit	ShortLifeSample	5905	5745	5995	5715	Tinè (2009)
Italy	SItaly3	Favella	Beta165482	6940	40	Seed/Fruit	ShortLifeSample	5875	5755	5970	5730	Tinè (2009)
Italy	SItaly3	Favella	Beta71633	6910	60	Seed/Fruit	ShortLifeSample	5875	5725	5975	5670	Tinè (2009)
Italy	SItaly3	Favella	LTL203A	6890	50	Seed/Fruit	ShortLifeSample	5840	5720	5890	5670	Tinè (2009)
Italy	SItaly3	Favella	LTL204A	6793	40	Bone	ShortLifeSample	5720	5655	5740	5630	Tinè (2009)
Italy	SItaly3	Torre Sabea	TAN88066	6960	130	Seed/Fruit	ShortLifeSample	5985	5730	6070	5625	Guilaine and Cremonesi (2003)
Italy	SItaly3	Torre Sabea	TAN88247	6890	130	Seed/Fruit	ShortLifeSample	5905	5660	6025	5560	Guilaine and Cremonesi (2003)
Italy	SItaly3	Torre Sabea	Ly1448(OxA)	6860	45	Seed/Fruit	ShortLifeSample	5795	5675	5845	5655	Guilaine and Cremonesi (2003)
France	Liguria-Provence	Abri Pendimoun	GifA101334	6790	90	Charcoal	LongLifeSample	5770	5615	5880	5540	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	GrA20195	6790	50	Charcoal	LongLifeSample	5720	5645	5765	5615	Binder and Sénépart 2010
France	Liguria-Provence	Abri Pendimoun	GrA26895	6605	40	Seed/Fruit	ShortLifeSample	5615	5510	5620	5485	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	GrA26897	6500	40	Seed/Fruit	ShortLifeSample	5515	5380	5535	5370	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	GrA29403	6725	45	Seed/Fruit	ShortLifeSample	5705	5570	5720	5555	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	GrA29528	6650	45	Seed/Fruit	ShortLifeSample	5625	5545	5640	5490	Binder and Sénépart (2010)

France	Liguria-Provence	Abri Pendimoun	Ly5339	6310	90	Seed/Fruit	ShortLifeSample	5465	5205	5475	5055	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	Ly5340	6490	75	Seed/Fruit	ShortLifeSample	5520	5370	5615	5315	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	Ly5690	6550	80	Seed/Fruit	ShortLifeSample	5620	5390	5635	5360	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	Ly5691	6160	130	Seed/Fruit	ShortLifeSample	5295	4945	5465	4780	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	Ly5692	6610	110	Seed/Fruit	ShortLifeSample	5640	5475	5725	5360	Binder and Sénépart (2010)
France	Liguria-Provence	Abri Pendimoun	Ly6495	6565	75	Charcoal	LongLifeSample	5615	5475	5635	5375	Binder and Sénépart (2010)
Italy	Liguria-Provence	Arene Candide	UB 2424	6700	145	Charcoal	LongLifeSample	5725	5491	5899	5368	Binder and Sénépart (2010)
Italy	Liguria-Provence	Arene Candide	LJ 4143bis	6910	110	Charcoal	LongLifeSample	5967	5709	5999	5631	Binder and Sénépart (2010)
Italy	Liguria-Provence	Arene Candide	LJ 4144	6490	100	Charcoal	LongLifeSample	5540	5357	5629	5233	Binder and Sénépart (2010)
Italy	Liguria-Provence	Arene Candide	UB 2423	6980	115	Charcoal	LongLifeSample	5981	5751	6059	5662	Binder and Sénépart (2010)
Italy	Liguria-Provence	Arene Candide	LJ 4143	6870	100	Charcoal	LongLifeSample	5871	5663	5983	5621	Binder and Sénépart (2010)
Italy	Liguria-Provence	Arene Candide	Beta 110,542	6830	40	Seed/Fruit	ShortLifeSample	5737	5670	5790	5639	Binder and Sénépart (2010)
France	Languedoc	Pont de Roque-Haute	Lyon245 (oxa)	6745	70	Charcoal	LongLifeSample	5725	5615	5765	5525	Guilaine et al. (2007)
France	Languedoc	Pont de Roque-Haute	Ly7607	6850	65	Charcoal	LongLifeSample	5795	5665	5880	5630	Guilaine et al. (2007)
France	Languedoc	Peiro Signado	Ly8399	6770	55	Charcoal	LongLifeSample	5715	5635	5755	5560	Briois (pers. Communication)
France	Languedoc	Peiro Signado	Ly8400	6840	65	Charcoal	LongLifeSample	5785	5660	5880	5625	Briois (pers. Communication)

(continued)

Table 14.2 (continued)

Country	Region	Site	Lab Number	Uncal BP	SD	Material		Calibration 1 s		Calibration 2 s		References
France	Languedoc	Peiro Signado	Ly5689(SacA-13,452)	6925	45	Seed/Fruit	ShortLifeSample	5845	5740	5965	5720	Briois (pers. Communication)
France	Languedoc	Peiro Signado	Ly5688(SacA-13,451)	6910	40	Seed/Fruit	ShortLifeSample	5840	5735	5890	5720	Briois (pers. Communication)
France	Languedoc	Peiro Signado	Beta 330,612	6770	40	Charcoal	LongLifeSample	5710	5640	5730	5625	Briois (pers. Communication)
Spain	East Spain	Cova d’en Pardo	Beta231879	6610	40	Bone	ShortLifeSample	5615	5510	5620	5485	Soler et al. (2013)
Spain	East Spain	Cova d’en Pardo	Beta231880	6660	40	Seed/Fruit	ShortLifeSample	5630	5555	5650	5510	Soler et al. (2013)
Spain	East Spain	El Barranquet	Beta221431	6510	50	Bone	ShortLifeSample	5530	5380	5610	5365	Bernabeu Aubán et al. (2009)
Spain	East Spain	El Barranquet	Beta239379	6510	50	Bone	ShortLifeSample	5530	5380	5610	5365	Bernabeu Aubán et al. (2009)
Spain	East Spain	Cova d’en Pardo	Beta231877	6240	40	Bone	ShortLifeSample	5305	5080	5310	5065	Soler et al. (2013)
Spain	East Spain	Mas d’Is	Beta162092	6600	50	Seed/Fruit	ShortLifeSample	5611	5491	5621	5481	Bernabeu Aubán et al. (2003)
Spain	East Spain	Mas d’Is	Beta166727	6600	50	Seed/Fruit	ShortLifeSample	5611	5491	5621	5481	Bernabeu Aubán et al. (2003)
Portugal	Tagus	Almonda	OxA9287	6445	45	Bone	ShortLifeSample	5475	5375	5485	5325	Zilhão (2011)
Portugal	Tagus	Almonda	OxA9288	6445	45	Bone	ShortLifeSample	5475	5375	5485	5325	Zilhão (2011)
Portugal	Tagus	Caldeirao	OxA1035	6330	80	Bone	ShortLifeSample	5465	5215	5480	5075	Carvalho (2008)
Portugal	Tagus	Caldeirao	OxA1034	6230	80	Bone	ShortLifeSample	5305	5070	5370	4980	Carvalho (2008)
Portugal	Tagus	Caldeirao	OxA1033	6130	90	Bone	ShortLifeSample	5215	4960	5300	4845	Carvalho (2008)
Portugal	Tagus	Senhora da Alegria	Beta339602	6380	30	Charcoal	LongLifeSample	5465	5315	5470	5305	Valera (2013)
Portugal	Tagus	Pena d’Agua	Wk9214	6775	60	Charcoal	LongLifeSample	5720	5635	5780	5560	Carvalho (2008)
Portugal	Tagus	Pena d’Agua	ICEN1146	6390	150	Charcoal	LongLifeSample	5515	5210	5625	5010	Carvalho (2008)

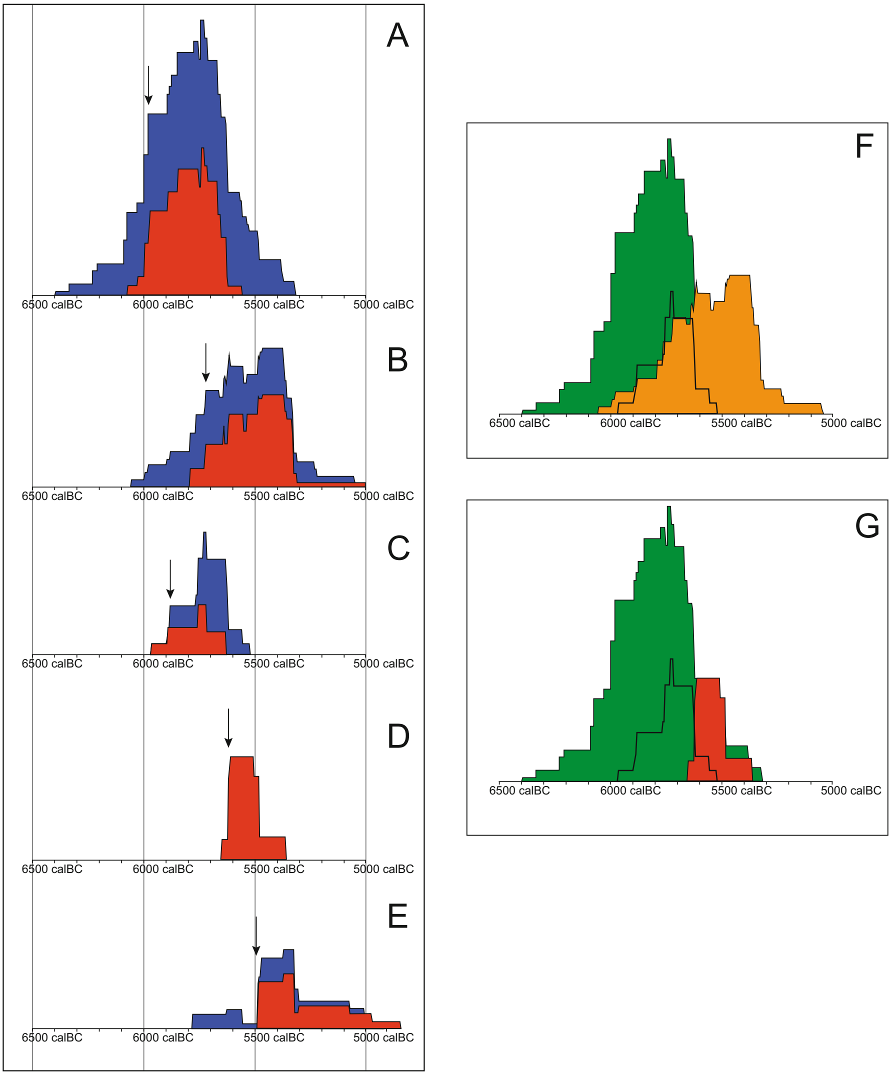

Fig. 14.1 Weighted cumulative histograms of the radiocarbon dates listed in the Table 14.2; calibration at 2-sigma calBC. *On the left*: (**a**) Southern Italy, (**b**) Liguria and Provence, (**c**) Languedoc, (**d**) East Spain, (**e**) Tagus. In *blue*, all samples, in *red*, short-life samples. The *arrow* indicates the emergence of the first pottery. *On the right*: Comparison of the weighted cumulative histograms. (**f**) Southern Italy in *green*, Liguria and Provence in *orange*, and Languedoc in *black*; (**g**) Southern Italy in *green*, Languedoc in *black*; East Spain in *red*.

After the 2-sigma calibration (using OxCal 4.2) of each data we performed the cumulative histograms of Fig. 14.1. These have been made by adding blocks of equal interval for the total range of each radiocarbon data. This procedure gives similar results to the “sumprob” function of the Oxcal (Evin et al. 1995; Perrin 2014).

Fig. 14.2 West Mediterranean selected sites and regions used in Table 14.3

We performed only the histograms for those regions that have a) good radiocarbon data set and b) clear archaeological sequence. Using these criteria we excluded all regions except Southern Italy, Liguria-Provenze, Languedoc, East Spain, and Tagus, in Portugal. Comparing the histograms it seems clear that there is a chronological shift as we move to the west. This is well defined if we exclude Liguria-Provence region, where the dating dispersal is very broad. Keeping all of these in mind the best starting points for the beginning of the Neolithic in each region are around 6000 BC in Southern Italy; around 5800 BC in Languedoc; around 5600 BC in East Spain; and around 5500 BC in Tagus region, Portugal.

In order to select sites, we do not consider if pottery assemblages of this window are more or less related to the "*impressa*" style or its technical system, strictly speaking. Rather we focus on the available radiocarbon data (cf. above) to select the very first pottery assemblages in each region of the North-Western Mediterranean.

We use the 2-sigma calibration of radiocarbon data of any layer, and decide to include it in our analysis if its chronological distribution crosses at least 20% of the temporal window. Figure 14.2 shows the selected sites and regions in which they are grouped. There are two exceptions to the rule. Although the Tyrrhenian sites (Giglio and Stephanu) are not dated, we decided to include them because they are commonly assigned to the *impressa* phase (Brandaglia 1991; Manen 2007; Cesari et al. 2014). The same criterion applies for two of the sites included in region Ebro 2, Abrigo de la Dehesa and Mendandia (García-Martínez de Lagrán 2014), two sites with very high radiocarbon dates.

14.3.3 The Ceramic Data Set and the Statistical Approach

Table 14.3 shows the data set for all sites grouped by regions. There are some problems we need to clarify before explaining our methodological procedure. First, there is great variability in the sample sizes of both sites and regions. There are also problems with their chronology. In some cases it is just unknown, while in others we have doubts about the concrete position of the site within the 200-year window we use. And finally we have a clear gap in the spatial continuity of the regions (Figs. 14.1 and 14.2). Our intention in grouping sites into regions is twofold:

- First, to minimize problems of biased sample due to a misrepresentation or overrepresentation. Because we have different kinds of sites (e.g., caves, villages), maybe with some specific functionality, and whose assemblages are diversely collected (small trenches, open-area excavations, survey collections, and so on), it seems clear that using single-site units is not a good strategy. Merging collections from different sites and layers is a good way to minimize this bias.
- Second, using temporal windows of any duration we assume that all layers we select have the same duration, but as layers are the result of a cumulative process of uncertain duration, slight differences could exist between them. Consequently, as different durations, although small, will result in different attribute composition or relative frequencies in the resulting sample, it seems that using single-site samples to compare could create more confusion.

Keeping all this in mind we decided to use a tentative strategy, selecting different subsamples from Table 14.3 and analyzing the results. In each case we perform the same protocol. First we obtain a distance index between regions. We use the Brainerd-Robinson proximity index; this index, developed in Archaeology to compare between counts of data, gives a result between 0 and 200, this latter value being a perfect similarity (DeBoer et al. 1996). It is calculated as the sum of the absolute values of the differences between percentages of two datasets. This procedure gives us a similarity matrix between each pair of samples. Using the formula (BRindex-200)*-1- to avoid negative values, we transform the original values into a dissimilarity matrix, ready to be used in the next step. Then, we use the Mantel test (Mantel 1967) as a way to evaluate if "cultural distance," measured as distance in using different decorative techniques, is correlated with "geographic distance" (using Chebyshev distance). The result gives a number that we can read as a correlation coefficient. The test consists in calculating the correlation of the entries in the matrices, then permuting the matrices, and calculating the same test statistic under each permutation and comparing the original test statistic to the distribution of test statistics from the permutations to generate a p-value. The number of permutations defines the precision with which the p-value can be calculated (e.g., a p-value of 0.05 means that we can reject the null hypothesis: in our case that "cultural distance" and geographic distance are not correlated). All statistical calculations were performed using the R software (R Development Core

Table 14.3 Archaeological data set. Decorative techniques by sites and regions. Item *Dos* and *Tres* + means combinations of two (dos) or three and more (tres+) decorative techniques

Sites	Regions	A	A1	A1a	A1a1	A1a2	A1a3	A1b	A1c	A1c1	A1c2	A1c3	A1d	A1e	A1e1	A1e2	A2	A2a	A2b	A3	A3a	A3a1
Torre Sabea		64	44	12	10	2	0	0	27	3	19	5	0	5	5	0	9	6	3	11	2	2
Favella		91	83	17	17	0	0	1	29	8	16	5	0	36	31	5	0	0	0	7	0	0
	Sitaly3	**155**	**127**	**29**	**27**	**2**	**0**	**1**	**56**	**11**	**35**	**10**	**0**	**41**	**36**	**5**	**9**	**6**	**3**	**18**	**2**	**2**
M. Candelaro		14	8	2	2	0	0	0	4	1	2	1	0	2	2	0	1	1	0	4	2	2
Rendina		13	11	3	3	0	0	0	5	0	3	2	0	3	2	1	1	0	1	0	0	0
Trasano		7	6	3	3	0	0	0	3	0	2	1	0	0	0	0	1	0	1	0	0	0
	SItaly4	**34**	**25**	**8**	**8**	**0**	**0**	**0**	**12**	**1**	**7**	**4**	**0**	**5**	**4**	**1**	**3**	**1**	**2**	**4**	**0**	**0**
Isola dei Giglio		37	31	25	23	1	1	0	6	0	4	2	0	0	0	0	0	0	0	1	0	0
Campu Stephanu		5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tirreno	**42**	**36**	**30**	**28**	**1**	**1**	**0**	**6**	**0**	**4**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**
Arene Candide		43	33	14	9	5	0	0	8	2	1	5	4	7	4	3	0	0	0	4	0	0
Pian del Ciliegio		6	5	3	1	2	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0
Pendimoun		10	10	3	3	0	0	0	3	0	3	0	0	4	2	2	0	0	0	0	0	0
Caucade		12	5	2	1	1	0	2	0	0	0	0	0	1	1	0	1	1	0	2	0	0
	Liguria	**71**	**53**	**22**	**14**	**8**	**0**	**2**	**13**	**3**	**5**	**5**	**4**	**12**	**7**	**5**	**1**	**1**	**0**	**6**	**0**	**0**
Peiro Signado		109	40	20	19	1	0	0	15	4	5	6	0	5	5	0	0	0	0	11	0	0
Pont de Roque-Haute		47	40	21	17	2	2	0	11	3	6	2	8	0	0	0	0	0	0	1	0	0
	Languedoc	**155**	**79**	**40**	**35**	**3**	**2**	**0**	**26**	**7**	**11**	**8**	**8**	**5**	**5**	**0**	**0**	**0**	**0**	**12**	**0**	**0**
Forcas II		7	5	3	4	1	0	0	2	1	0	1	0	0	0	0	0	0	0	1	0	0
Balma Margineda		6	5	3	3	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	0
	Ebro1	**13**	**10**	**6**	**7**	**1**	**0**	**0**	**3**	**2**	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**2**	**0**	**0**
Peña Larga		1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mendandia		8	6	0	0	0	0	0	2	0	2	0	0	1	1	0	0	0	0	2	0	0
Abrigo de la Dehesa		3	3	3	0	0	0	0	2	0	2	0	0	1	0	1	0	0	0	0	0	0
	Ebro2	**11**	**9**	**1**	**1**	**0**	**0**	**0**	**6**	**1**	**5**	**0**	**0**	**2**	**1**	**1**	**0**	**0**	**0**	**2**	**0**	**0**
Barranquet		18	10	4	3	1	0	0	6	1	3	2	0	0	0	0	0	0	0	3	0	0
Mas d’Is		22	14	8	3	4	1	0	4	3	1	1	0	1	1	0	1	1	0	3	0	0
en Pardo		1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
	East Spain	**38**	**23**	**12**	**6**	**5**	**1**	**0**	**10**	**4**	**4**	**2**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**6**	**0**	**0**
Cariguela16		25	19	6	2	3	1	1	8	3	2	3	4	0	0	0	1	1	0	5	0	0
Nerja nv4		1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SESpain	**26**	**20**	**6**	**2**	**3**	**1**	**2**	**8**	**3**	**2**	**3**	**4**	**0**	**0**	**0**	**1**	**1**	**0**	**5**	**0**	**0**
Cabranosa		5	3	2	2	0	0	0	1	0	0	1	0	1	1	0	0	0	0	2	0	0
Padrao		4	4	2	1	1	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0
	Algarve	**9**	**7**	**4**	**3**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**2**	**2**	**0**	**0**	**0**	**0**	**2**	**0**	**0**
Senhora da Alegria		34	22	7	5	2	0	0	11	5	4	2	3	1	1	0	0	0	0	5	0	0
Pena d’Agua		6	5	2	2	0	0	0	2	0	1	1	0	1	1	0	0	0	0	1	0	0
Caldeirao		1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tagus	**41**	**28**	**10**	**8**	**2**	**0**	**0**	**13**	**5**	**5**	**3**	**3**	**2**	**2**	**0**	**0**	**0**	**0**	**6**	**0**	**0**

A3a2	A3b	A3b1	A3b2	A4	B	B1	B2	B2a	B2c	Dos	Tres +	A + B	A1 + A2	A1 + A3	A1 + A4	A2 + A3	A2 + A4	A3 + A4	B1 + A1	B1 + A2	B1 + A3	B1 + A4	B2 + A1	B2 + A3
0	9	5	4	0	0	0	0	0	0	5	0	0	0	3	0	0	0	0	0	0	0	0	0	0
0	7	7	0	1	2	2	0	0	0	21	1	2	0	3	1	0	0	0	2	0	0	0	0	0
0	**16**	**12**	**4**	**1**	**2**	**2**	**0**	**0**	**0**	**26**	**1**	**2**	**0**	**6**	**1**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**
0	2	2	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	1	1	0	0	2	2	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
0	**3**	**3**	**0**	**1**	**2**	**2**	**0**	**0**	**0**	**2**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
0	1	1	0	5	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	**1**	**1**	**0**	**5**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
0	4	4	0	6	2	2	0	0	0	7	0	1	0	3	1	0	0	0	1	0	0	0	0	0
0	0	0	0	1	1	1	0	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	2	2	0	4	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0
0	**6**	**6**	**0**	**11**	**4**	**4**	**0**	**0**	**0**	**11**	**0**	**3**	**0**	**3**	**2**	**1**	**0**	**1**	**3**	**0**	**0**	**0**	**0**	**0**
0	11	11	0	58	0	0	0	0	0	5	0	0	0	1	2	1	0	1	0	0	0	0	0	0
0	1	1	0	6	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	**12**	**12**	**0**	**64**	**0**	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**0**	**2**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
0	1	1	0	1	4	4	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	1	1	0	0	2	2	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	**2**	**2**	**0**	**1**	**6**	**6**	**0**	**0**	**0**	**2**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	2	0	0	4	4	0	0	0	3	0	3	0	0	0	0	0	0	3	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	**2**	**2**	**0**	**0**	**4**	**4**	**0**	**0**	**0**	**3**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**
0	3	3	0	5	0	0	0	0	0	3	0	0	0	1	0	1	0	1	0	0	0	0	0	0
0	3	3	0	4	5	5	0	0	0	6	0	4	0	1	0	0	0	0	4	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	**6**	**6**	**0**	**8**	**5**	**5**	**0**	**0**	**0**	**9**	**0**	**4**	**0**	**2**	**0**	**1**	**0**	**1**	**4**	**0**	**0**	**0**	**0**	**0**
0	5	5	0	0	8	7	1	0	1	9	2	5	1	4	0	0	0	0	3	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	**5**	**5**	**0**	**0**	**8**	**7**	**1**	**0**	**1**	**9**	**2**	**5**	**1**	**4**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**
0	2	2	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	**2**	**2**	**0**	**0**	**2**	**2**	**0**	**0**	**0**	**2**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**
0	5	5	0	7	1	1	0	0	0	7	0	0	0	1	3	1	0	1	0	0	0	0	0	0
0	1	1	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	**6**	**6**	**0**	**7**	**2**	**2**	**0**	**0**	**0**	**8**	**0**	**1**	**0**	**1**	**3**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**

Team 2013) employing various packages. Thus, for the Brainerd-Robinson index we used the Statnet package (Goodreau et al. 2008) (script by Peeples (2011)); the Chebyshev distance was calculated using MASS (Ripley et al. 2014); and for the Mantel test, we used the Vegan package (Oksanen et al. 2013).

14.4 Results

As what we hope to find is a spatial pattern, so that each region must be close to its neighbors and, at the same time, their cultural distance will be greater as the geographic distance increases from the point of origin (in this case Southern Italy), the result of the Mantel test must be a positive value. Since our interest is to explore the feasibility of using an evolutionary perspective with regard to the known data, we designed a strategy in several steps.

As expected, using all regions (Sample 1) gives a positive number meaning that there is some correlation between both distance matrices. But this is very small and the associated *p*-value cannot eliminate the null hypothesis. In order to investigate the effect of small sample sizes in the result we exclude Ebro 2 (Sample 2), Ebro 1 (Sample 3), Algarve (Sample 4), and all three regions with N $<$ 20 (Sample 5), getting similar results (see Table 14.4). What is interesting to point out is the relative value obtained when using different regions: the worst is when including

Table 14.4 Mantel test results for each sample (see text Section 14.3 for explanations). In shadow the best results

Sample	Regions	Correlation	p-value
1	All regions	0.137	0.218
2	No Ebro2	0.149	0.204
3	No Ebro1	0.091	0.286
4	No Algarve	0.102	0.29
5	Tagus, SE Spain, East Spain, Languedoc, Liguria-provence, Tirreno, SItaly3&4	0.048	0.411
6	Tagus, SE Spain, East Spain, Languedoc, Liguria-provence, SItaly3&4	0.208	0.181
7	SE Spain, East Spain, Languedoc, Liguria-Provence, Tirreno, SItaly3&4	0.267	0.123
8	Tagus, East Spain, Languedoc, Liguria-Provence, Tirreno, SItaly3&4	−0.056	0.521
9	East Spain, Languedoc, Liguria-Provence, SItaly3&4	0.637	0.071
10	**SE Spain, East Spain, Languedoc, Liguria-Provence, SItaly3&4**	0.529	0.009
11	**East Spain, Languedoc, Liguria-Provence, Tirreno, SItaly3&4**	0.195	0.241
12	Tagus, East Spain, Languedoc, Ligruria.Provence, SItaly3&4	0.211	0.213

Ebro2 and the best when using Ebro1. In any case, excluding SItaly3&4 derives in worse results.

This probably means that the sample size is not the only factor affecting our data. For this reason, in the next step we try to investigate the effect of those collections whose chronology was more doubtful: Tirreno and Tagus, or whose samples have been obtained essentially from a single site, or may be affected by different sampling strategies like survey vs. excavation (SE Spain and Tirreno).

Thus, for the next step we exclude Ebro1, Ebro2, and Algarve, preserving S Italy3&4. Then, we alternatively exclude Tirreno (Sample 6), Tagus (Sample 7), and SE Spain (Sample 8) and, finally, all three samples (Sample 9). The best correlation (0.637) with a *p*-value of 0.071 is obtained when excluding all three regions (Sample 9). Clearly the results get worse when we include Tirreno and Tagus, which is confirmed by sample 8, where we use both samples and we get a negative correlation. To better understand these results we tried three more samples. Here we used the same regions as in sample 9, adding SE Spain (sample 10), Tirreno (Sample 11), and Tagus (Sample 12). Only when we use SE Spain we obtain a good result, but not with the other two samples.

Summarizing, this approach, although preliminary and in need of further research, provides interesting results which lead us to conclude by highlighting some issues:

1. There is some evidence for supporting a correlation between culture and distance as have been measured here.
2. But, this correlation is restricted to certain regions. Those regions are S Italy 3&4, Liguria-Provence, Languedoc, East Spain, and, possibly, SE Spain. When we include the other regions, this picture is obscured.
3. Finally, it may be tempting to interpret these results as the effect of the hitchhiking hypothesis acting on certain regions, while for the remainder it can be argued either there is insufficient information, or the presence of different mechanisms (such as interaction with Mesolithic groups). But interpreting the patterns presents several problems arising not only from the empirical data, but also from the methods themselves.

14.5 Discussion

At the beginning of this work, we emphasized our intention to explicitly explore the possibility that a process of demic spread, if it occurred, would leave its footprint on the empirical record. From the perspective of the evolutionary theory, we emphasize the hitchhiking hypothesis as a reasonable process. We indicated that, if so, one would expect a strong pattern of correlation between spatial distance and cultural distance. We chose the Mantel test as an adequate tool to measure this correlation from decorative techniques, the archaeological proxy of "Neolithic cultures" used here. Our results suggest that this is a promising perspective, but there are some issues that must be resolved before interpreting whether or not these results confirm our initial hypothesis.

The spatial structured pattern of cultural diversity could be the result of two main processes: branching and blending (leaving aside the problems of convergence), that is, vertical or horizontal transmission. Or, as is more probable in the case of culture, some combination of both. In the case of the hitchhiking hypothesis, branching must be the important driver in the first steps of the Neolithic spread, but as we move away in time, the interaction between groups will introduce blending in the evolutive history of West Mediterranean Neolithic. That is the reason we decided to limit the samples to those sites chronologically closest to the beginnings of pottery sequence in each region.

But, as has been pointed out (Crema et al. 2014), the common analytical procedures (reconstructing phylogenetic trees, the Mantel test, the Retention Index (RI), or the ∂-score) used to evaluate between both drivers present some problems when we try to interpret their values as a result of one process or the other. The methodological approach conducted by Crema and his colleagues (2014) and our own results indicate that there are two groups of problems to be faced. One concerns the adequate methods to distinguish between branching and blending; the other stems from the nature of the archaeological record itself.

As branching and blending are processes that could be affected by multiple underlying factors (like mutation rate, fission rate and distance, interaction frequency, and others) producing a wider range of correlation coefficients that could be misinterpreted as signals of either process, and, as is usual in "cultural evolution," the most frequent scenario is a mixed one: it seems clear that we need other tools to face these problems. This is the same as admitting that the systemic features we can observe are the result of the actions of individuals and groups interacting with each other and with the environment. An approach based on the theories and methods developed from complex adaptive systems (CAS) emphasizes precisely this aspect (Bernabeu et al. 2012; Barton 2014). Viewing human societies as CAS entails a focus on information flow, decision making, interactions at multiple scales of organization, and nonlinear dynamics in which individual agency generates system-level emergent phenomena. But we have no way to directly observe the dynamics of ancient human societies at either the actor or the system level.

The use of agent-based models (Crema et al. 2014) and other virtual modeling techniques (Barton 2014), as a tool to generate alternative scenarios, based on well-known rules, which can be used to evaluate against the archaeological record, seems a good alternative. But even in this case, we will face the problem of the nature of the archaeological record itself. This is because the material record is a static, disorganized, fragmentary, and cumulative set of objects produced by different actors over long periods of time. And consequently, the patterns that we can observe are indirect, material consequences of emergent phenomena (S. Shennan 2002; Barton et al. 2012).

Since we cannot observe directly or indirectly the dynamic phenomena in which we are interested, we need to look for suitable archaeological proxies. In this work we have chosen to use decorative techniques; but we could also use the pottery designs (motifs) or stone tools instead of ceramics. It is entirely feasible that distinct kinds of material culture may have been characterized by a greater or lesser incidence of branching or blending (Jordan and Shennan 2009). As these authors wrote, "By simultaneously comparing and contrasting the descent histories of several material-culture traditions we open out the potential to explore increasingly complex patterns of population-scale cultural evolution…" (Jordan and Shennan 2009, p. 343).

Furthermore, the information we collect is only one part of the past, mediated by sampling problems that include archaeological practices. This is not only the problem of adequate sample sizes; it includes the sampling strategies and in the case of pottery to decide the adequate observational units (e.g., fragments or vessels?). Of course, the indexes we use to measure the diversity between samples can also affect the outcome. Consequently, we need to evaluate between the various possibilities offered by the use of quantitative indexes, as used here, and qualitative, as the Jaccard (Shennan et al. 2014) or Hamming distances, based on presence/absence data.

Finally, any archaeological unit, as a layer in a cave or the filling of a pit, is the result of a more or less long-lasting process. Moreover, this process could be different for each sample unit (e.g., site layer), despite archaeologists classifying them in the same period (e.g., Early Neolithic). This implies that we need to develop temporal strategies if we want to compare between real data and model data. In this work we used the temporal windows as a way to define the duration of the archaeological units. But we need more precision in the radiocarbon dates as well as a more appropriate way to decide when a level may or may not be included in a specific time window.

All of these factors can introduce biases in the real data as have been shown by some of the examples in our work. In conclusion what we need is not only more and better empirical data, but also a new way to understand how we can improve and use the archaeological record to evaluate between alternative virtual data derived from the use of computational simulations. It seems clear to us that future works, on which we are working, will be specifically addressed to these questions.

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Chapter 15
The Revolution in Studies of the Neolithic Transition in the West Mediterranean

Stephen Shennan

It has long been clear that farming spread into Europe along two different routes, a northern one through the Balkans and Central Europe and a southern one along the northern coast of the Mediterranean. Studies of the northern route represented by the Starčevo–Kőrös–Criș complex in the Balkans and then the Linearbandkeramik, from the western Carpathian Basin to the coast of the English Channel, have been well established for decades. Until recently, however, the Mediterranean expansion west of the Aegean was much less known. Far less work had been carried out and the chronological details, especially those concerning the relationship between the Mesolithic and the Neolithic, were very unclear, not least because the vast majority of radiocarbon dates came from cave and rockshelter sites with complex and often disturbed stratigraphies. In particular, the fact that both Mesolithic and Neolithic material were apparently found in the same layers led to the conclusion that the mechanism of the transition in the Mediterranean must have been the gradual and piecemeal adoption of elements of a farming way of life by local foragers. In the last 20 years our knowledge has been transformed. There has been a revolution in the understanding of the spread of farming in the West Mediterranean, especially in Iberia, thanks to the work of a new generation of archaeologists trained in the methods of modern scientific archaeology, from fieldwork to laboratory analysis and computer-based modelling.

Key to the new understanding was the recognition in the late 1990s of the importance of ‘chronometric hygiene’ in the evaluation of radiocarbon dates and their contexts. Once bulk samples of charcoal potentially subject to old wood effects and from uncertain contexts were excluded and only short-lived samples from reliable contexts considered, it became apparent that the initial spread of farming in the West Mediterranean was rapid, in fact even more rapid than the one

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through Central Europe, with farming reaching the Atlantic coast of Portugal by no later than c.5300 BC, if not earlier. Moreover, it involved the full Neolithic 'package' of domestic crops and animals, as well as pottery, not just domestic animals used in a pastoralist version of previous Mesolithic ways of life. The widely accepted conclusion has been that farming spread as a result of a maritime expansion of pioneer farmers from the East Mediterranean (Zilhão 2001). The chapters in this volume by Juan-Cabanilles and Martí and by García-Puchol et al. (2017) and Pardo-Gordó et al. (2017) give us effectively the current state of play on this topic. Pardo-Gordó et al. (2017) demonstrate further the importance of using only carefully evaluated samples, in this case as the basis for testing simulation models of the spread of farming. Juan-Cabanilles and Martí (2017) show that the areas where farming first arrived in the mid-6th millennium BC lacked Mesolithic populations and in some cases had done so for hundreds of years. Where Mesolithic and Neolithic sites have similar dates they are always a considerable distance apart. García-Puchol et al., (2017) after another careful evaluation of samples, show that radiocarbon date densities in the Western Mediterranean increase with the arrival of farming, suggesting that farming led to local population growth, and consistent with the pioneer farmer model. They also note that after a peak at c.5300 BC numbers of sites and dates decline markedly after c.5200 BC, a pattern of rise and decline that is also found at a more local scale in several different Spanish regions (Bernabeu Aubán et al. 2016).

In all these respects developments in the West Mediterranean turn out to be similar to regions further north. This is of considerable interest from a cultural evolution point of view because we can compare the cultural, economic and social patterns that developed along two different independent branches that had a common source in the Aegean region and came into contact again in France after a thousand years of separation (cf. Silva and Steele 2014). The pioneer farmer model now proposed for the West Mediterranean expansion has long been the preferred model for the LBK expansion in Central Europe among the great majority of scholars. Moreover, though Fernández and Reynolds in this volume are cautious in their interpretations of the increasingly available ancient DNA evidence, in my view we can now be confident on the basis of the genetic data that in both the LBK and the West Mediterranean we are seeing the results of the demographic expansion that the pioneer farmer model always assumed. There is a very limited amount of admixture with existing local populations, not least because, with one or two exceptions based on marine or riverine resources, Mesolithic populations would have been generally very low. In fact, the isotope evidence presented in the chapter by Salazar-García et al. (2017) indicates that Neolithic farmers, even in coastal locations, relied mainly on terrestrial sources of protein and did not have a sophisticated maritime fishing technology.

In both the Mediterranean and Central European cases too the process of expansion is not a gradual one but involves very rapid so-called leapfrog colonisation, a pattern of discontinuous long-distance movement, which Pardo et al. (2017) (and see also Bernabeu Aubán et al. 2015) show has the best fit to the dates of initial farming arrival in the West Mediterranean when combined with a preference for areas with better farming conditions and an avoidance of areas that were already settled. Given that the West Mediterranean colonisation must have resulted to a considerable degree from maritime movement, the leapfrog nature of the movement from one suitable area to another is unsurprising, indeed unavoidable. However, movement did not wait until currently settled regions were fully occupied; for example, there were already settlements in eastern Spain when occupation in Italy was only half way to the peak density shown in García-Puchol et al.'s (2017) Fig. 3. The same is true for the LBK. The initial spread from the Carpathian Basin to the Rhine was extremely rapid even though the population densities in the initial stage of dispersal were only a relatively small fraction of those that were reached 150–200 years later. The payoff for this dispersal pattern remains unclear, all the more so since isolated communities at the dispersal frontier would have been vulnerable to so-called Allee effects; that is to say, although high population densities resulting in interference competition are usually deleterious to survival and reproductive success, when local population densities are very low there are also dangers; individuals can be subject to greater risk because of a lack of both reproductive partners and support in times of need.

There are strong indications too that, like the West Mediterranean farmers described by Cabanilles and Martí, the pioneer farmers of the Linearbandkeramik occupied areas that were largely devoid of Mesolithic occupation (Vanmontfort 2008) and there is little evidence of interaction between the two. In the case of the LBK, Zimmermann et al.'s (2009) analysis of its spatial distribution in Germany throws interesting light on why this might be the case. Although the LBK is found widely across central, western and southern Germany, its distribution is restricted to only a small fraction of the total area, and even to a fraction of the loess soils that were suitable for LBK farming, so the impact on Mesolithic ways of life could have been minor. A recent genetic and isotope study (Bollongino et al. 2013) provides an insight into forager-farmer interaction in Central Europe that might also be relevant in at least some parts of the West Mediterranean. In this case isotopic analyses of skeletons from a burial cave used in the 4th millennium BC, 2000 years after the regional arrival of farming, found two distinct groups, one with an agricultural dietary signature, and the other with a forager and freshwater fish one. Individuals in the latter group had Mesolithic mitochondrial haplotypes indicating that they were descendants of Mesolithic individuals who had kept a foraging lifestyle through this time. On the other hand, several of the individuals in the farming dietary group also had Mesolithic haplotypes demonstrating that some individuals of Mesolithic ancestry had become farmers. It will be interesting in the future to see if such situations where Mesolithic groups, perhaps in upland areas, maintain separate lifestyles for centuries alongside farming groups are found in the West Mediterranean.

A further parallel between the Central European and West Mediterranean expansion is the pattern of population 'boom and bust' in many regions. With the arrival of agriculture population increases very significantly but then declines markedly, albeit not to the pre-agricultural level (Shennan et al. 2013, Timpson et al. 2014, García-Puchol et al. 2017, Bernabeu Aubán et al. 2016). In both regions the reasons for these declines remain unclear: is it driven by climate change affecting the productivity of farming or does it arise from entirely endogenous processes within the social subsistence system, with population increase exceeding local environmental carrying capacities and/or depleting local soils, or is there some combination of the two, perhaps the former exacerbating the latter. At the end of the LBK, as populations are beginning to decrease, there is ever-increasing evidence of inter-group violence (e.g. Meyer et al. 2015), including massacres, while in early Neolithic southeast Italy Robb (2007) points to evidence of a high incidence of healed cranial trauma and of two possible massacres to suggest that warfare was common. Thus, in this respect too the parallels between the expansion of farming populations in the two regions and its consequences may be close; but this needs much more work to clarify.

When we turn to the comparison of subsistence there are two elements to consider, the major environmental differences but also the effects of cultural transmission, though when a tradition embodies a successful adaptation it may be effectively impossible to distinguish between the two. Successful subsistence practices will be transmitted from year to year and generation to generation, but of course they are potentially subject to changing environmental circumstances that affect the payoff to different practices, whether local environmental change or movement to new places with different circumstances. At the same time, the process of group fission involved in demographic expansion can lead to disconnection from social networks that provide ongoing information about crop performance and can also result in random drift effects depending on both the specific knowledge and practices of the fissioning part of the community and the particular seed stock and animals they take with them. When the movement is by sea rather than land these processes are likely to be even more accentuated and, in the case of crops, will also have an influence on the weeds that are transported.

By the time the northern and southern European farming expansions split from the Aegean in the late 7th millennium BC, farming was a well-established system that had spread there from Central Anatolia several hundred years before. Halstead (e.g. 1996) argued that in the Aegean region it was a system based on the intensive cultivation of small garden plots whose continued fertility was ensured by systematic manuring, and in a series of publications Bogaard (e.g. 2004) has argued that this was the farming system that characterised the LBK in Central Europe. It seems that Pérez-Jordà et al. (2017) accept this assessment as well. So far as I am aware, the detailed analytical work to assess the extent of manuring has not yet been carried out in the West Mediterranean but one implication of this system is that it should lead to relatively limited indications of human impact on the environment through forest clearance. This is generally the case in Central Europe and it seems that the West Mediterranean situation is similar, with the opening up of the woodland only starting at the beginning of the 5th millennium (Badal et al. 2017). Finally, the weed assemblage from the site of La Draga in Catalonia (Terradas et al. 2017) is largely made up of annuals, which also points to permanent cultivation as per the Halstead-Bogaard model. However, it is important to note that the La Draga Cardial culture may be the result of a second wave of West

Mediterranean farming expansion rather than the initial Impressa one (see below), for which we do not yet have comparable evidence.

On the other hand, whereas West Mediterranean crop diversity is similar to that in southeast Europe, that is not the case in Central Europe, where the LBK shows a much reduced range, even when those crops, in particular pulses, with a limited environmental tolerance outside the Mediterranean are excluded (Colledge et al. 2006). It may be that the reduced range is a result of founder effects at the beginning of the LBK. While the reasons for the West Mediterranean diversity may be to do with the similarity of growing conditions to the Southwest Asia homeland, it is worth noting that it was sustained despite the likely filtering effects of sea travel noted above. On the other hand, what emerges very clearly from Pérez-Jordà et al.'s (2017) study is the regional diversity in crop spectra within the West Mediterranean region, for reasons that may be partly environmental but may also be linked with the presence of different cultural traditions; thus, there is a contrast between the initial Impressa in Valencia, the south French coast and Liguria, apparently more associated with hulled wheats, and the later Cardial ceramic tradition where free-threshing wheats are more prevalent. The significance of these different early Neolithic traditions, raised by a number of the chapters, will be considered again below.

In terms of the animal economy, the contrast between the Mediterranean pattern, where the domestic fauna assemblages are generally dominated by sheep/goat, and the Central European pattern, with a predominance of cattle and pig, is well known. The latter pattern is already apparent at the Early Neolithic sites in the northern Balkans while the Mediterranean pattern is similar to that in Greece. The analyses by Manning et al. (2013) unsurprisingly demonstrated a strong correlation between environmental conditions and the frequency of these different species, and associated with this is the much greater evidence for pastoral mobility in the West Mediterranean (McClure and Welker this volume). If we think in cultural evolutionary terms the implication of these results is that the transmission signal is much weaker than the environmental one; in effect, the environmentally based differential payoffs are visible and it is relatively easy to respond to them. On the other hand, it could also be argued that, inasmuch as the West Mediterranean pattern had already developed in the Aegean, there was no need to change: a successful adaptation had already been developed.

In this context some of the most interesting results in this volume come from the chapter by Spiteri et al. (2017), which demonstrates the use of Impressed and Cardial early Neolithic pottery for the processing of dairy products. The same is true of the LBK in Central Europe (e.g. Salque et al. 2013) and it also occurs in the ancestral Aegean-Anatolian region (Evershed et al., 2008). In other words, both milking and milk processing practices were consistently transmitted along both branches of the pioneer farming expansion, despite all the potential vicissitudes of successive community fissioning and the potential loss of variation in small communities as a result of drift. This points to strong cultural selection in its favour; indeed, it may have been a key factor in the success of these expansions. Where the predicted effects of drift are seen very clearly, however, is in the mitochondrial diversity of early Neolithic cattle; in this respect both the West Mediterranean and Central Europe areas show reductions to low levels with increasing distance from their SE European origin (Scheu et al. 2015), reflecting successive founder effects as communities split, moved and established new settlements, regardless of whether those movements were by land or sea.

Of course, other lines of evidence for cultural transmission come from the artefacts associated with the expanding and fissioning communities in Central Europe and the West Mediterranean. Traditionally here most of the evidence is placed on pottery because of its widespread presence in Neolithic communities, and more generally because we know that pottery-making as a skill is acquired by a process of learning from more skilled, usually older, individuals in the community, very often closely related to the learner. However, ethnoarchaeological work in recent decades (e.g. Gosselain 2000; Roux 2007) has shown that different elements of the pottery-making process are likely to produce different transmission signals: decorative attributes are highly visible and therefore potentially easy to pick up, even from very superficial contact, including just seeing the vessels themselves. This is not the case with invisible attributes, such as the vessel fabric, which will require knowledge and experience of the production process. It is even less the case with the techniques of vessel forming, which involve the mastery of specific motor habits that are not easy to change. Thus Gosselain (2000) has proposed that in Africa there is correlation between the distribution of vessel-forming techniques and of languages, because both are acquired early in life within a community and thereafter remain largely unchanged. In fact, vessel-forming techniques are a specific example of the acquisition of what Mauss (2006) called 'les techniques du corps', which likewise are specific to different backgrounds and upbringings with regard to the technique concerned, whether it be swimming, walking or using a spade. This does not mean that these specific techniques arise to assert identity but rather that they are unconsciously acquired in the process of growing up in a particular place and time and as a result have a particular transmission history that can be distinguished by an external analyst. However, they do also have practical consequences for the people themselves, as in Mauss's example of the English World War 1 soldiers who could not use the French spades with which they were provided and which had to be replaced by English ones.

In this connection the chapter by Ibáñez et al. (2017) on West Mediterranean harvesting tools and techniques is an especially interesting one, because, as they say, harvesting can be done in a variety of different ways which to some degree at least are equally effective alternatives, and are likely to be relatively conservative. Thus different sickles involving different harvesting techniques are likely to reflect different cultural traditions. Once again, we have a pattern that fits the expectations of cultural transmission in the context of the pioneer farming model, as the authors propose. In the Aegean origin area both the La Marmotta and La Draga sickle types are present and the same is true of the earliest agricultural settlements in southern Italy. To the north and west the early sites only have the La Marmotta type and the same is true of the early sites in Valencia and areas of Spain to the south, a pattern consistent with the loss of the other sickle type in the process of maritime colonisation, whatever route this took. The La Draga-type sickles are found in northeast Italy in the mid-6th millennium and then spread westwards through the coastal regions of southern France as far as Catalonia, where they are found at the site of La Draga itself, and the interior of Iberia. The authors make a very plausible case that this results from a second, largely land-based, Neolithic expansion associated with Cardial Ware, which led to the gradual substitution of La Marmotta sickles by La Draga ones among the pre-existing Impressa farming communities. By the end of the 6th millennium this had led to a stable pattern in sickle distribution, with the La Draga type found from northern Italy to northern Iberia and the La Marmotta type in southern Iberia, which was never reached by the second expansion, and peninsula Italy.

This may seem an elaborate edifice to build on the basis of sickle types, but in support of the dual expansion process proposed, the authors point to Vigne's (2007) analysis of the characteristics of the early Neolithic domestic sheep of the West Mediterranean. This showed that sheep from the Impressa context of Pont de Roque-Haute in Languedoc were more robust than Cardial sheep and were similar to those from Corsica and Central Italy, suggesting a maritime arrival. The Cardial sheep were similar to those from Liguria and could have had an origin in continental northern Italy, and ultimately the northern Adriatic (Vigne 2007, Fig. 127). Further support for these separate waves of expansion, the authors suggest, is given by the difference in cattle mtDNA haplotypes between La Draga (T1) in Catalonia and Cova del Or in Valencia (T3).

Cultural evolutionary theory is explicitly espoused in the final paper by Bernabeu et al. (2017) in their explanation of spatial and temporal diversity in the distribution of decoration techniques on the earliest pottery in the West Mediterranean. So far as I am aware, this is the first attempt to carry out such a study at such a large spatial scale. In the case of the central European LBK farming expansion a number of cultural evolution modelling studies of ceramic decoration patterns have been carried out (e.g. Shennan and Wilkinson 2001; Bentley and Shennan 2003; Kandler and Shennan 2015) but they have been at a local or regional scale. They have generally taken as a null hypothesis that the transmission of the attributes concerned is ‘unbiased’, that is to say that there are no forces taking their frequencies in any particular direction as they are transmitted through time. Rather, the relative frequency of the use of different motifs continues as before and is only modified by the fact that innovations occasionally occur and that, purely as a result of the operation of chance in finite populations, some motifs will not be copied at all in a given time period and will therefore disappear, while others will happen to be copied slightly more often. This apparently simple and straightforward process can result in massive changes in motif frequencies over time (see e.g. Bentley et al. 2004). Results have tended to show minor departures from this model, in favour of a slight preference for less common motifs or more recent innovations. Little evidence has been found for conformist transmission, an *exaggerated* preference for the most common motifs, which will in any case tend to be transmitted more frequently under the unbiased model, such as might be expected if decoration is signalling group identity in some way.

It is unbiased transmission that is effectively at the heart of the 'cultural hitchhiking' model proposed and tested by Bernabeu et al., (2017) following Ackland et al. (2007), to account for the distribution of the different early Neolithic decorative techniques in the West Mediterranean. Cultural traits without any intrinsic benefits of their own can spread if they are linked with traits that do have such an advantage. The demic expansion of pioneer farming communities provides precisely such a context. The farming economy provides the advantageous trait because it leads to demographic expansion. Pottery as a technology is part of that advantageous complex, for example for milk processing, as we have seen, but the particular decorative attributes that spread are simply in this context the 'cultural baggage' that happens to be associated with the groups that are growing and fissioning and founding new settlements; they are transmitted with them, along with other attributes that are invisible to us, such as their language. If cultural hitchhiking based on unbiased transmission is the mechanism responsible for the spread of the decorative techniques we should expect drift and innovation to be operating, and probably quite powerfully given the small size of the communities concerned, so that assemblages further from the origin in time and space should become increasingly different from those at the origin. In the event, Bernabeu et al.'s (2017) analysis of the relationship between the distance of the sites from a south Italian origin and the between-site assemblage similarity does show the expected correlation between increasing distance and decreasing inter-assemblage similarity but the results are by no means conclusive, as they explain, and further work is required.

Stepping back now to look at the overall pattern of the spread of farming into Europe along its Central European and West Mediterranean branches we can see that the processes involved are extremely similar. Small groups of pioneer farmers with an origin in the Aegean-Anatolian area were moving rapidly by so-called leapfrog colonisation into new territory, much of which was only very thinly occupied, if at all, by foragers. With regard to the crop aspect of the economy there was a difference between the two branches in that the northern branch underwent a loss of variation, perhaps arising from a combination of founder effects and the move into a new environment, which did not occur in the Mediterranean, where the reasons for the great variation in crop assemblages between different sites remain to be fully explored. Nevertheless, in both regions there is reason to believe that farming was based on a small-scale intensive garden system, for which the digging sticks from La Draga (Terradas et al. 2017) provide us with evidence of the techniques used. In the case of stock-keeping there is a broad environmentally based difference between an emphasis on cattle in the north and sheep/goat in the south but dairying and processing of milk products in pottery are fundamental to both sets of communities and the transmission of the relevant practices must have been under strong cultural selection. In contrast, the genetic diversity of the domestic cattle in both regions decreases to the west/northwest, reflecting the founder effects on the cattle stock arising from successive colonisation episodes. The interesting work presented here on the transmission of harvesting techniques and ceramic decoration methods is not yet paralleled in Central Europe but is extremely thought provoking in providing a strong indication of the different transmission processes and outcomes associated with 'techniques of the body' on the one hand, and ceramic decorative attributes on the other; in the case of the latter there is some reason to believe that the patterns may result from cultural hitchhiking. Finally, we see in the West Mediterranean, as in many other areas of Europe, that early farming was not a guaranteed passport to ongoing cultural and reproductive success but was subject to 'boom-and-bust' processes that we still do not fully understand.

Of course, much remains to be resolved and understandings will certainly change in the future. Nevertheless, together with other recent publications (e.g. Manen et al. 2014), the chapters in this volume show how our understanding of the Neolithic transition in the West Mediterranean has been transformed by a new generation. The book represents a timely taking stock of current knowledge on the research frontier in the light of the exciting developments of the last two decades that have been pioneered by the authors in this volume and others.

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