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5. CHARCOAL ANALYSIS: WOOD EXPLOITATION AND FIRE

5.1 INTRODUCTION

Taforalt Cave or Grotte des Pigeons is located approximately 40 km from the Mediterranean coast, at 720 m a.s.l. within the Beni Snassen mountains, which are part of the SE foothills of the Atlas/Baetic System. The influence of the Mediterranean climate is remarkable in this region (see **Chapter 1**). The cave is located within the thermo-Mediterranean bioclimatic zone (Rivas-Martínez/Loidi 1999), with a well-marked moisture gradient from east (sub-humid) to west (semi-arid).

Because of its biogeographical particularities, the region around the Strait of Gibraltar (Baetic-Rifean region) has been identified as a hot-spot of plant diversity (Médail/Quézel 1997), although in recent times human modelling of landscape around the Rif and Beni Snassen areas, including intense deforestation, has become particularly evident. Interest in this biodiversity has led to some recent studies on flora and vegetation (e.g. Charco 1999; Valdés et al. 2002) but a diachronic long-term analysis is absolutely necessary to understand fully the genesis of current landscapes and their evolution under climate and/or human impact. Nowadays, the local vegetation is dominated by *Pinus halepensis* and *Tetraclinis articulata*, associated with *Quercus ilex* and *Juniperus* sp. and other sclerophyllous shrubs.

Taforalt marks a milestone in research on prehistory in North Africa and, particularly, on palaeobotanical analysis since the mid-20th century, as some authors working in the cave began laying the methodological and interpretive bases of the discipline. Thus, S. Santa (1958-59) highlighted the suitability of archaeological charcoal for the reconstruction of past vegetation, using thin sections of charcoal from Taforalt. Other pioneering works carried out in North Africa include those by L. Balout (1952), J. Momot (1955), S. Santa (1961) and M. Couvert (1977). These researchers put forward some of the main lines of interpretation in anthracology and even proposed a climate approach based on the flora identified in prehistoric charcoal assemblages (Couvert 1976; Couvert/Roche 1978). For the early 1990s, we must highlight the work performed on several deposits from eastern Morocco by L. Wengler and J.-L. Vernet (1992) and the summary by K. Neumann (1992) about Late Quaternary Mediterranean vegetation, including North Africa.

In 2007, the PhD thesis by S. Ward (University of Oxford) is another reference work, because it comprises several sites in North Africa (including Taforalt) and Gibraltar, and it offers an extensive discussion about the changes in vegetation and their influence on the main cultural transitions (among other topics); some of the results of this thesis will be considered below.

Despite these pioneering works, there was a general lack of regional, systematic studies of plant macro-remains in North Africa until the team led by Lydia Zapata and Leonor Peña-Chocarro began to undertake several studies within the framework of the PALEOPLANT project (ERC-2013-CoG) (Barton et al. 2016; Morales et al. 2013; 2015; 2016; Zapata et al. 2013; Carrión Marco et al. 2018; among others). The importance of charcoal analysis in North Africa, besides offering knowledge about landscapes of the past in a region where there is still a considerable information gap, is based on the local provenance of the wood, thus enabling the reconstruction of the mosaic of landscapes that existed in the past as well as their exploitation over time.

Methods of Charcoal Analysis

In this volume, we present the study of wood charcoal assemblages from Sectors 8 and 10, although the analysis of charcoal from other sectors (2 and 9) is ongoing; other, non-woody charred plant remains are considered in Chapter 6.

Charcoal analysis is based on the botanical identification of carbonised wood, i.e. determining which species the charcoal is derived from. Each fragment is observed under a reflected light brightfield/darkfield optical microscope with different lenses ranging from 50x to 1000x magnification. Wood anatomical features are compared with specialised literature on plant anatomy (Greguss 1955; 1959; Jacquiot 1955; Jacquiot/Trenard/Dirol 1973; Neumann et al. 2001; Schweingruber 1990; among others) and a reference collection of current charred wood. The charcoal from Taforalt was analysed in the Laboratory of Prehistory and Archaeology Milagro Gil-Mascarell at the University of Valencia, where there is a complete collection of Mediterranean woods, including numerous woody species from North Africa.

For the standard analysis, charcoal is broken manually and no chemical treatment is needed, so these samples can be used later for radiocarbon dating (Vernet/Bazile/Evin 1979). For the observation of specific features and for taking pictures, we used a Hitachi S-4100 scanning electron microscope (SEM) held at the Central Service for Experimental Research Support (SCSIE) at the University of Valencia.

The frequency of taxa identified is measured as a percentage of fragment counts when the sample contains a statistically meaningful number of charcoals, generally between 100 and 200 fragments, depending on the taxonomic diversity of the sample (Badal 1992; Chabal 1988; Chabal/Fabre/Terral/Théry-Parisot 1999). The identified taxa reflect part of the woody vegetation that was exploited and, thus, present among the local flora (Chabal 1997), so charcoal analysis is a reliable tool for palaeovegetation reconstruction. However, other species could have been present in the environment but not reflected in the anthracological spectra, as in the case of herbaceous plants or woody species that were not collected for socio-cultural reasons.

Charcoal was very abundant in both Sectors 10 and 8 of Taforalt; the former presents a number of *in situ* human skeletons and a limited accumulation of sediment, so there is not a highly developed stratigraphy, but there may be lateral dispersion of charcoals from as yet unidentified locations. On the other hand, Sector 8 offered a long sequence covering an LSA-relevant chronology between c. 23,000-12,600 cal BP (underlain by still earlier material).

The macro-botanical remains were obtained by flotation of the sediment. Charcoal was very abundant, so we analysed between 100 and 170 fragments per sample in Sector 8, a sufficient number to stabilise the taxonomic curve and ensure a representative assemblage, that is, a number likely to include more or less the full range of exploited species (Chabal 1997). In the cemetery area, we analysed numerous samples to be sure that there are no biases in the spatial distribution of the taxa. To do this, between 50 and 100 fragments per sample were analysed, giving a total of 1786 fragments for these burial levels. In both sectors, charcoal fragments of different sizes (>4 mm and 4-2 mm) were selected for analysis using a column of sieves. Once analysed, no significant differences in the taxonomical content of the samples were observed depending on size, so the results are presented together.

Particular Identification Challenges

During the analysis, we had some challenges in botanical identification, mainly regarding certain species, or groups of species, that are anatomically very similar to each other (fig. 5.1).

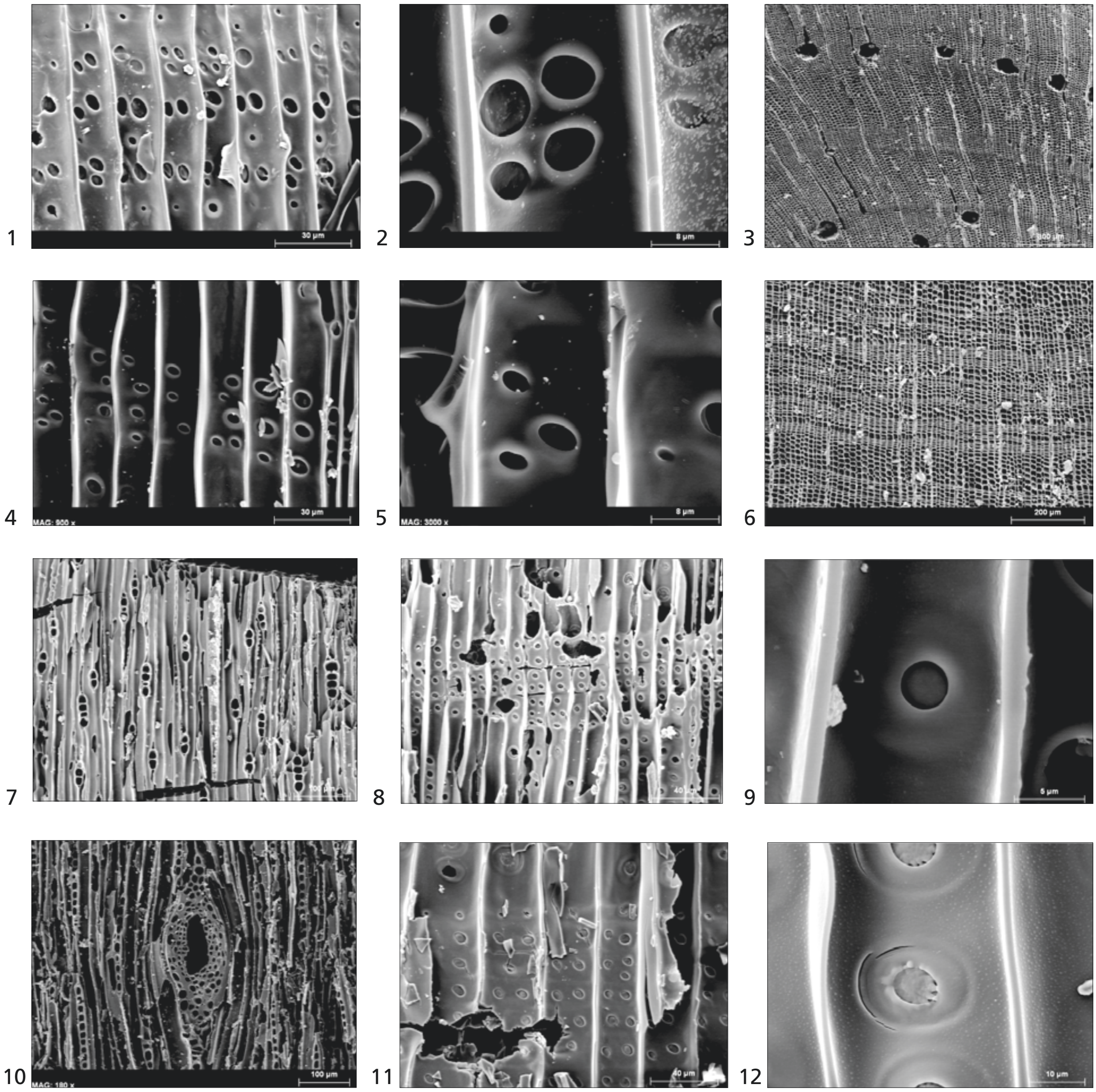

Fig. 5.1 SEM photographs of conifers identified at Taforalt: **1** *Pinus* tp. *pinaster*, radial section, crossfield pits x900, Sector 10; **2** *Pinus* tp. *pinaster*, radial section, crossfield pits x3000, Sector 10; **3** *Pinus* tp. *pinaster*, cross-section, x80, Sector 10; **4** *Pinus* tp. *halepensis*, radial section, crossfield pits x900, Sector 10; **5** *Pinus* tp. *halepensis*, radial section, crossfield pits x3000, Sector 10; **6** *Juniperus/Tetraclinis*, cross section, x130, Sector 10; **7** *Juniperus/Tetraclinis*, tangential section x200, Sector 8 G100; **8** *Juniperus/Tetraclinis*, radial section, crossfield pits x600, Sector 8 G100; **9** *Juniperus/Tetraclinis*, radial section, bordered pit x3000, Sector 8 G100; **10** *Cedrus* sp., tangential section x180, Sector 8 G97; **11** *Cedrus* sp., radial section, crossfield pits x600, Sector 8 G97; **12** *Cedrus* sp., tangential section, bordered pit x2000, Sector 8 G97.

In the charcoal assemblage from Taforalt, at least four conifer species were identified, belonging to the Pinaceae and Cupressaceae families, whose identification involved some challenges in terms of anatomical discrimination. With regard to the family Pinaceae, *Pinus* tp. *pinaster* and *P.* tp. *halepensis* were identified, plus a percentage of fragments that could not be determined beyond genus level (*Pinus* sp.). According to the atlases, differences between different pine species are marked by the distribution of the resin ducts along the growth rings that are visible on the cross section of wood, as well as by cross-field pits and ray tracheid wall morphology on the radial section (Greguss 1955; Jacquiot 1955; Schweingruber 1990; Riou-

Nivert 1996). Two groups of pines, the highland species and the lowland/Mediterranean ones, are clearly differentiated thanks to the presence of fenestriform pits in the cross-fields of the former group; at Taforalt, all the pines identified belong to the Mediterranean group.

Another problematic group is the Cupressaceae: this is the case of *Juniperus*, which is anatomically very close to *Tetraclinis articulata* (both are present in the area today) (Charco 1999). The main difference between them is the presence of wedge-shaped cell walls around the bordered pits in *Tetraclinis* (Schweingruber 1990, 145), a feature that is absent in junipers and which can only be (rarely) confirmed by observation under SEM equipment. A morphometric study of ancient samples from Taforalt compared to current individuals from the reference collection (some from the area of the site) did not provide conclusive results in terms of anatomical discrimination (as other variables related to combustion, conservation, etc., also influenced the observation of these anatomical features), so we identified the taxon *Juniperus/Tetraclinis*, as already discussed by Zapata et al. (2013) in other analyses of the region.

Finally, the taxon *Cedrus* sp. was identified on the basis of its distinctive anatomical characteristics (Schweingruber 1990, 111), such as high rays (up to 30 cells) and radial resin canals on the tangential section or tracheid pits with scalloped tori.

5.2 PALAEOENVIRONMENT

The Species Collected and their Ecological Significance

As mentioned above, the species most frequently collected by the inhabitants of Taforalt were conifers (**fig. 5.1**), which account for approximately 80 % of total wood remains found in Sector 10 and 87 % in Sector 8. Their presence in the cave indicates that they would probably have been accessible and abundant in the vicinity of the site. Despite uncertainty about the identification of certain conifers, as discussed in the preceding section, some of these species offer interesting ecological information.

Juniperus/Tetraclinis systematically appear in considerable percentages in both Sectors. Despite the aforementioned problems distinguishing between these genera, their presence can provide some very interesting ecological information. The entire Mediterranean region of North Africa is a natural area inhabited by Phoenician juniper (*Juniperus phoenicea*), in addition to *Juniperus oxycedrus* in coastal areas; it is also the natural habitat of the araar tree (*Tetraclinis articulata*), so it can be assumed that all of these species could be present in the charcoal remains from Taforalt, as they are currently found in mixed formations (Charco 1999). All of these are characterised by very open heliophilous forest formations, which are accompanied by Labiatae, *Cistus* and Fabaceae shrubs in the area being studied, as well as *Olea europaea* and *Pistacia lentiscus*, among others.

Pines are also common in the charcoal of both Sectors, with the advantage that they can often be identified at species level, which can provide very precise ecological and/or edaphic information. The pines identified at Taforalt are two lowland species: *Pinus pinaster* and *P. halepensis*. Although *P. halepensis* is currently the most widely distributed species of pine in North Africa, it is a minority species in the area that we are studying, principally the natural range of *P. pinaster*. In Morocco, it is an essentially calcicolous species, although it can also grow on siliceous soils. These are considered climax forests, which have decreased largely as a result of anthropic causes (Charco 1999). In the western Rif, *P. pinaster* is found alongside the Phoenician juniper in warm areas and sandy soils, but also with cedar and fir formations at an altitude of 2000 m, which shows how adaptable it is to different temperatures. The associated flora is also varied, as is the habitat in which they grow but, at the altitude where the site is located, different species of Fabaceae, cistus, rosemary, *Quercus coccifera*, *Tetraclinis articulata*, *Juniperus oxycedrus* and *Pistacia lentiscus* can be found, among others.

Cedar is present in the upper units of Sector 8. It is a highly adaptable species in terms of soil type and even altitude (from 2500 to 900 m in particularly cool, damp terrain). Its distribution is characterised by rainfall, although in this regard there is also a great deal of variability: the annual rainfall in the Rif cedar area is currently within the 2000-1700 mm range, although in other areas of the Maghreb it can be as low as 450-500 mm (Charco 1999, 76). Many of the cedar forests are poor in understorey vegetation, as this tree generates very dense, almost monospecific masses. However, in the central Rif, on siliceous soils, there are formations with *Pinus pinaster* ssp. *maghrebiana* that grow in a humid to hyper-humid environment. Cedars also grow alongside *Juniperus oxycedrus*, *Taxus baccata*, *Acer opalus* and *A. monspessulanum*, *Prunus avium*, *Quercus ilex* and *Quercus canariensis*, among other species. Some of these taxa could be present in the charcoal found at Taforalt, as they have been identified at least at genus level (*Acer*, evergreen *Quercus*, deciduous *Q.*), indicating the presence of this type of forests within the radius of firewood collection by the occupants of the cave.

The case of *Quercus* is interesting, as only two types can be identified from its wood: evergreen and deciduous. In terms of evergreens, both tree (*Q. ilex*) and shrub (*Q. coccifera*) species grow naturally in the surroundings of the site; as for deciduous species, *Q. canariensis* grows from thermo-Mediterranean to meso-Mediterranean zones, i. e. in warm, temperate or cool climates, but in a humid or hyper-humid environment. In the supra-Mediterranean zone, this species is mixed with *Q. faginea*.

Riparian vegetation is weakly represented by a few fragments of wood from *Salix-Populus* and *Tamarix*.

Species of scrub and other shrubs are varied in the anthracological record of Taforalt but, in terms of percentages, they are scantily represented, accounting for approximately 1.5 % of all the charcoal from Sector 8 and somewhat less than 3 % of that from Sector 10. The families Cistaceae, Compositae, Labiatae and Fabaceae are present, as are Monocotyledons, *Olea europaea*, *Pistacia*, *Rhamnus-Phillyrea* and *Rosmarinus*; most of these taxa form the thermo-Mediterranean sclerophyllous scrubland that is characteristic of the zone in which the site is located.

Local Woody Flora, Landscape and Climate Reconstruction

The species documented show that the cave's inhabitants frequented different ecological environments from which firewood was gathered and which could be found in the more or less immediate surroundings of the site. In general, all the species identified could live anywhere from the mountainous areas of the Rif and Beni Snassen to the coastal plain, and the position of the site provides access to both environments (**fig. 5.2**). The taxa identified do not vary significantly in terms of their presence throughout the sequence obtained for Sector 8, although quantitative changes can be seen in the composition of the spectra, which could be attributed to possible variations in the composition of vegetation and/or changes in firewood gathering strategies in the different formations that could be accessed from the cave.

The sequence from Sector 8 dates from c. 15,000 to 12,600 cal BP for the Grey Series, which has been analysed in this study, and dating back to 31,000 cal BP (MSA – the two lowest bars in **fig. 5.3**, retained for comparison with the overlying LSA period samples) in the Yellow Series. As mentioned above, the taxa with the greatest presence throughout the sequence are basically pines and Cupressaceae and, to a lesser extent, evergreen *Quercus*. All of these can grow in a warm, temperate environment without requiring too much water, except for cedar, which requires more moisture and grows in cooler climates (**fig. 5.2**), suggesting

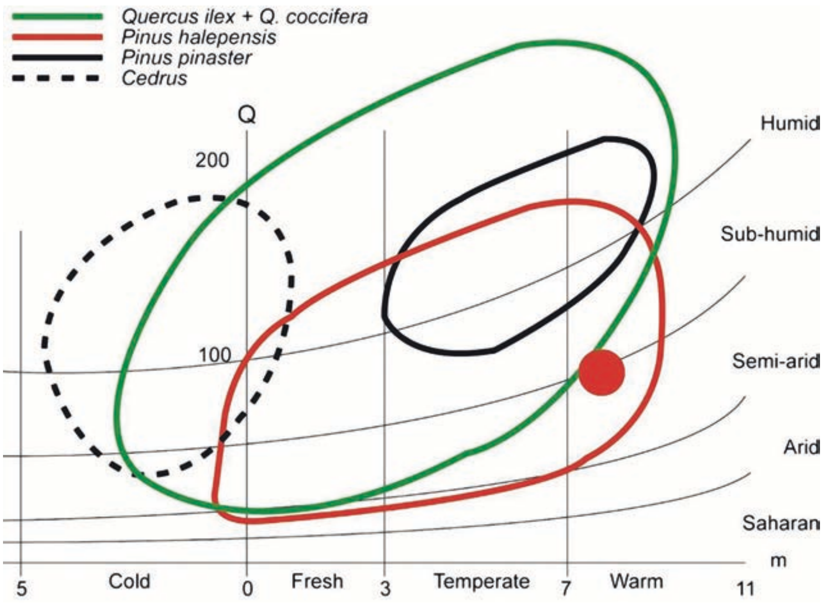

Fig. 5.2 Distribution of some ecological markers identified at Taforalt according to the Emberger's precipitation index 1936, 1939 (**Q**), and the mean minima of the coldest months (**m**); based on Quézel (1976), modified; the red spot marks the current bioclimatic location of Taforalt.

that there was access to a different type of ecosystem than the one currently found in the immediate surroundings of the cave.

In the diagram obtained for Sector 8 (**fig. 5.3**) some changes can be seen in the composition of the floristic spectra from the base to the top of the sequence.

In the Yellow Series, the presence of charcoal is much scarcer than in the Grey Series. The earliest LSA occurs in S8-Y4spits1-2 with the prior transition being estimated at S8-Y4spit3. The sediments in the latter show a distinct dry-cold (dust) episode but no changes were identified in the original charcoal samples (Ward 2007). In general, the abundance of *Juniperus/Tetraclinis* can be seen to occur across this mini-sequence, whilst there is a more modest presence of pines, of which three different species have been identified: *Pinus halepensis*, *P. pinaster* and *P. pinea*, the last of which is limited to just a few fragments (Ward 2007). There seems to be a noticeable peak in *Quercus* close to the appearance of the LSA (**fig. 5.3**). More detailed sampling of the lower YS would be necessary to explore the possibility of identifying short-term cooling events such as HE2.

The identification of predominantly *Pinus halepensis* in the YS (in modest percentages, approximately 5-10 %) coincides with the analyses carried out by pioneering researchers in the region, who noted the presence of this species in the charcoal found in the cave (Santa 1958-1959, cited in Neumann 1992). In our latest analyses, a greater presence of *P.* tp. *pinaster* can be seen, supported by the identification of scales of this species and comparative morphometric studies using SEM (**fig. 5.1**). In any case, all the pines identified are lowland species, the range of which may coincide throughout most of the territory, and it is not surprising that various species were present within the radius of firewood collection by the inhabitants of the cave.

The base of the Grey Series shows a massive presence of *Juniperus/Tetraclinis*, representing up to 90 %, and a pronounced lack of taxonomic diversity in general (following the trend already apparent in the top of the YS). The pine curve began at about 15,000 cal BP, with very modest values at first, but it later underwent a rapid and progressive expansion. There is also a continuous presence of evergreen *Quercus* (representing 1.5 to 3 %) and *Acer* sp., although the latter is much more sporadic. We cannot assess the presence of 20 % of this last species in an isolated unit (G98-2), unless it is due to a chance concentration of wood of this species, probably due to a heterogeneous distribution of charcoal at this level.

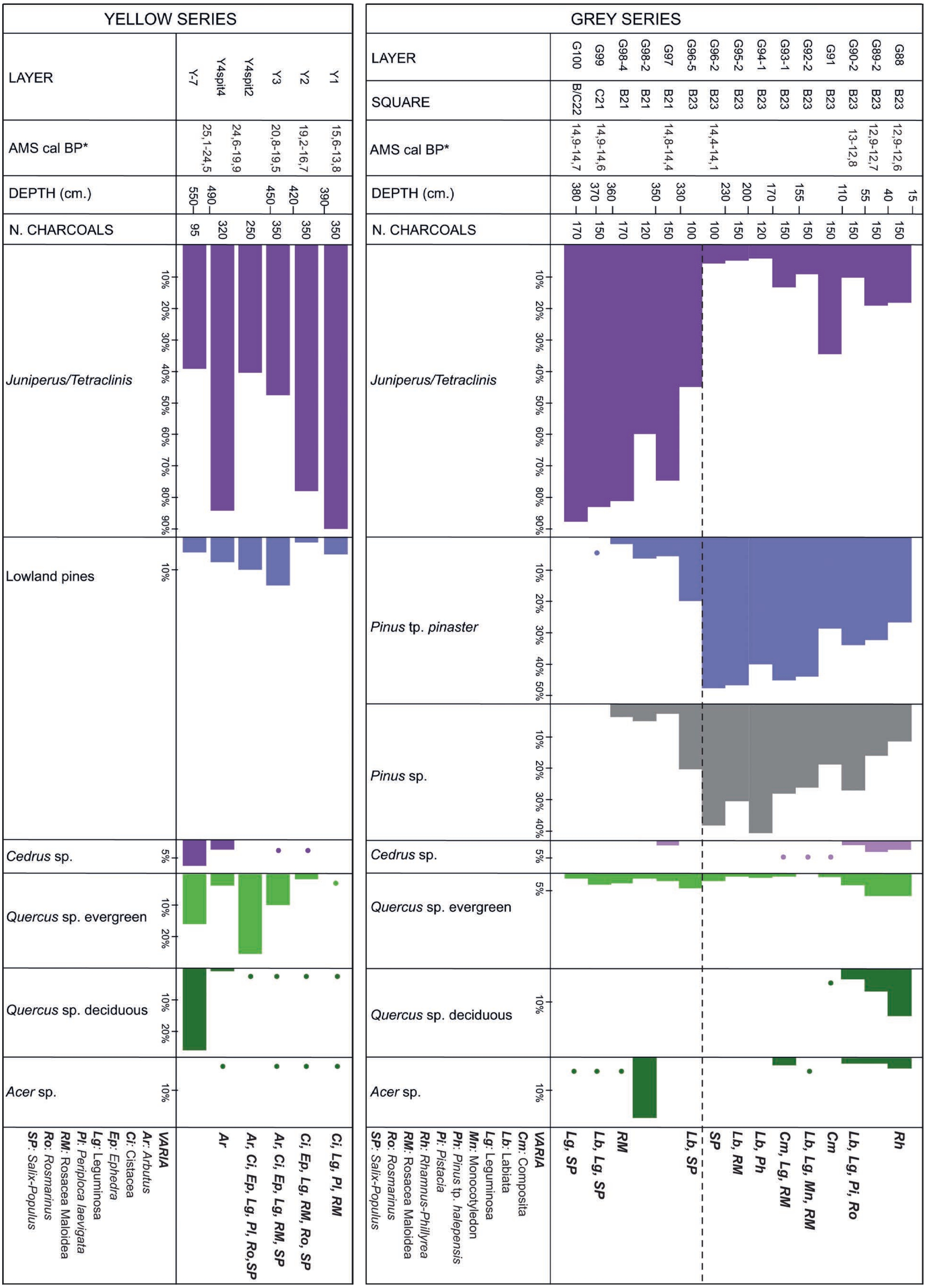

Fig. 5.3 Charcoal diagram of Sector 8; data from the Yellow Series synthesised from S. Ward's thesis (2007); (*) see the complete set of dates in tab. 4.1.

The most important change seen in the diagram begins at a level dated to 14,244-14,545 cal BP (OxA-23410) (tab. 4.1) using charcoal of *Juniperus/Tetraclinis* (cf. Barton et al. 2013). From that point on there is a clear replacement of what had until then been the dominant taxon, *Juniperus/Tetraclinis*, by pines, which then remain at values of 50 to 90 %.

Deciduous *Quercus* and *Cedrus* become more abundant towards the top of the GS sequence, which may indicate that the conditions became cooler and more humid (fig. 5.2). The chronology of the top of the Grey Series coincides with the start of the Younger Dryas, so cooler environmental conditions would have led to a descent in the altitude of cedar formations, making them more accessible for the inhabitants of Taforalt. In fact, cedar appears intermittently in the cave's sequence from low in the Yellow Series (dated to the MSA), almost completely disappearing from the middle of S8-Y4 (maybe just before the LSA) to S8-Y1, and reappearing in level G93 (fig. 5.3). This suggests that there were alternating humid phases, indicated by the presence of cedar and other similar taxa such as deciduous *Quercus*, and arid phases, as seen from the dominance of *Juniperus/Tetraclinis*, which have much lower moisture requirements.

Couvert/Roche (1978) noted the presence of *Cedrus* at Taforalt in a Yellow Series level (Roche XII equivalent to our S3[20-31]) dating to the earlier LSA, based on which they concluded that the conditions were cool and humid, which would have allowed forests of this species to grow at lower altitudes than at present. This leads to an interesting debate about the original range of cedars, which currently are rare in the surroundings of the site.

A rise in moisture would also be compatible with the aforementioned replacement of *Juniperus* by pines, as seen in the diagram of Sector 8, which began approximately 15 cal ka BP, as *Pinus pinaster* needs more moisture than junipers, despite being a species that basically prefers warm conditions.

The few anthracological sequences available for the region in question corroborate the systematic presence of *Juniperus* and *Tetraclinis articulata* formations that fluctuate with pines and with the *Olea-Pistacia lentiscus* combination in warmer areas when changes in humidity occur (Wengler/Vernet 1992). At Taforalt, earlier analyses carried out by Santa (1958-1959) and Couvert/Roche (1978) show the fluctuating presence of plant assemblages from different biogeographical contexts (albeit largely in an earlier, MSA, time-frame): a succession of supra-Mediterranean, humid vegetation (with cedar and oak), oro-Mediterranean (with cedar and junipers) and thermo- and meso-Mediterranean vegetation similar to the current vegetation (with pines, *Juniperus*, *Quercus ilex* and *Olea*) is recorded. Despite the occasional difficulty of correlating sequences from previous and recent works at Taforalt (see Chapter 2), the alternation between *Juniperus/Tetraclinis* and vegetation that grows in more humid conditions (*Cedrus, Pinus*), as well as the combination of *Cedrus* and deciduous *Quercus* at times when humidity increased and temperature decreased, constitute the main trends observed in the charcoal sequences. Judging from the presence of these species, at the altitude at which the site is situated, climatic fluctuations at the end of the Pleistocene would have been more evident than on the coastal plain, ranging between one or two vegetation zones (cited in Wengler/Vernet 1992).

5.3 PALAEOECONOMICS AND GENERAL HUMAN BEHAVIOUR

Identifying Human Input

The plants represented in a site's record are a human 'selection' from the biomass available in the surrounding environment for specific needs, in this case for use as fuel. Various studies have attempted to explain the parameters used for this selection, which may be aimed, if not at specific species, then at least at a certain type of diameter or physiological state (dry, dead, green wood, etc.), depending on the needs or purpose of the fire (Théry-Parisot 2001). Although there was a certain degree of selection of the wood that was used, the charcoal record of a long sequence with sufficiently repeated occupation ends up being representative of the surrounding vegetation, one of the paradigms of anthracological analysis that makes it possible to reconstruct the environment (Chabal 1997).

At Taforalt, it has been argued that all the species in the anthracological record are ecologically coherent with at least two types of plant formations (**fig. 5.2**), one that is more characteristic of sublittoral plains and one that is characteristic of the mid-montane zones of the Rif and Beni Snassen, the borders of which may have been in contact in the vicinity of the site and have fluctuated over time due to climatic changes. The species present in the charcoal therefore show the area from which firewood was collected by the inhabitants of the cave, which in turn adapted to changes that may have occurred in the range of plant formations.

The results seem to suggest a greater representation of tree or tall shrub species, specifically pines and *Juniperus/Tetraclinis*, followed by *Quercus* and *Cedrus*. Scrub species are scantily represented (at least in terms of percentage) despite the fact that, according to vegetation studies of the area, conifer formations should have had a rich understorey, with a variety of scrub species (Charco 1999). This may suggest that wood was gathered from tall shrubs or trees and that the use of scrub was marginal. In passing, it may be noted that we have found scrub species systematically in other comparable sites; the charcoal size can be smaller than in other species (just as is the original diameter), but scrub charcoals are usually preserved and identifiable.

The wood from different species of *Juniperus* has specific characteristics. In fact, these are not strictly speaking tree species, as they tend to branch out into several trunks from the base. Some studies carried out on present-day *Juniperus thurifera* formations have shown that it is very common for the species to have a shrub-like structure with several trunks (some produced more than 10 from the base) and perfectly synchronous stem growth, as shown by their growth rings (Bertaudière/Montès/Badri/Gauquelin 2001). The use of these plants would have been far more beneficial in terms of biomass than single-stemmed plants. In fact, extensive use of *Juniperus thurifera* specimens with these characteristics for various purposes (fuel, building, etc.) was observed in traditional Moroccan villages, and this species' huge capacity for regeneration after human exploitation was also noted (Barbero et al. 1990).

The presence of very narrow growth rings, with less than 100 microns of annual growth, was observed in many *Juniperus/Tetraclinis* fragments at Taforalt; the decrease in secondary growth of these genera is a characteristic of longer-living trees, so the presence of these narrow, straight rings (**fig. 5.1**, photo 6) might indicate the use of adult, long-living trees, i. e. we might infer the existence of a 'mature' forest.

With regard to pines, these are trees whose size and physiognomy differ somewhat from one species to another. The two main species identified at Taforalt, *P. halepensis* and *P. pinaster*, have low, accessible branches that would make them suitable for wood cutting. In the latter case, its lower branches die as the tree grows upwards, even in low-density formations, but once dead they remain adhered to the trunk, i. e. accessible as firewood.

One variable that allows inferences to be made about the type of wood gathered is the systematic presence of xylophagous microorganisms, primarily hyphae of fungi, as this may provide evidence of the use of dead wood collected from the forest. Several authors have suggested the possibility that prehistoric groups collected dead wood as fuel, since this would be an easy resource that would save the effort of cutting wood and it would be very suitable if they were seeking dry wood (Théry-Parisot 2001; Badal 2001; among others). One way to assess this would be, *a priori*, to note the systematic presence of fungi in archaeological charcoal. There is a great deal of debate about how this translates to the selection of green or dead wood, as experimental studies have shown that it is difficult to differentiate between contaminated dead wood,

contaminated live wood at the foot of the tree, or healthy wood that was contaminated during a more or less prolonged storage period. A system has been created to classify the effects of fungi on wood for application in archaeology (Théry-Parisot 2001; Moskal-del Hoyo et al. 2010; Henry/Théry-Parisot 2014; Vidal Matutano 2016; among others).
In the charcoal remains found at Taforalt, few cases of wood contaminated by fungi have been documented (less than 1 % of the fragments); S. Ward (2007) noted the very occasional presence of alterations resulting from fungi in the remains analysed, suggesting that the same trend applies to the materials analysed in both studies.
Another issue concerns specific fuel needs in terms of the type of fire that is required (flames, live coals, smoke, etc.), for which different species or different types of wood from the same species can be used. For example, kindling is generally needed to start the fire, for which dry dead wood and/or thin branches, scrub, etc. can be used, followed by a 'maintenance' fuel whose characteristics help to control the rate at which it burns, for example, by varying the moisture content of the wood (Henry 2011; Henry/Théry-Parisot 2014). These selection variables appear to be more important than the species selected. The characteristics of the charcoal found at Taforalt seem to indicate that wood with a medium or large diameter was selected, and more sporadic use was made of a wide range of accompanying species, including plants of different sizes and diameters.
However, a more detailed analysis of the remains shows the use of different parts of some plant species, such as the presence of pine bracts among the charred remains. It is important to mention that, whilst some of these bracts were recognised on the basis of their external morphology, most were identified only from their internal anatomy, as their outer appearance was the same as the rest of the charred wood, which indicates that they were treated in the same way during the burning process. The bracts that could be identified belonged to the *Pinus pinaster* species (see Chapter 6). The large size of the pine cones of this species and the separation of their scales once dried make them a very suitable fuel for lighting a fire. In fact, they are known popularly as 'fire starters', since they burn easily and are consumed without going out (López González 2007). This may have been what they were ultimately used for at Taforalt, as they appear systematically throughout the Sector 8 sequence.
The pine kernels of this species also are edible, so although they were used as fuel, it is entirely plausible that the pine kernels would have been eaten first. In any case, they can be removed by simply toasting the pine cones slightly (Morales et al. 2015; see Chapter 6), so their complete carbonisation supports the idea that they were subsequently reused on the fire. The presence of charred bracts at other sites also shows this double use: the pine kernels were eaten and the bracts subsequently used as fuel (Badal 1998).

Wood Collection in a Changing Environment?

In view of the above, there is a fundamental question that we must ask ourselves with regard to the changes observed in the Sector 8 sequence: was there a significant change in the vegetation or did the wood collection strategy change? Perhaps the vegetation around the cave remained essentially the same but its inhabitants accessed other formations that were further away from the cave.
Various ethnographic studies on hunter-gatherer groups show that the radius for gathering wood to meet daily needs, i. e. without seeking any specific type of fuel, could generally be within a maximum radius of 500 m from the site (Henry 2011). In the case of archaeological sites, it is difficult to define the radius of action for gathering firewood, as it is affected by several different variables, including the distribution of plant species in the past or the existence of specific fuel requirements.

As mentioned above, the ecological requirements of the taxa identified in the case of Taforalt refer to two types of formation, one sub-humid type that prefers cooler conditions, represented by the presence of cedars (and pines), and another type that grows in a largely semi-arid environment, with *Juniperus/Tetraclinis* formations. The dominance of these two types in the vicinity of the cave may have alternated according to variations in the humidity conditions. So, as proposed by Couvert/Roche (1978), cedar forests would have been more widespread than at present and access to these formations would have meant valuable new resources, since the rapid growth and large size of cedars yields more wood than other conifers (M'Hirit 1982; 1999).

One of the main arguments for claiming that there was an environmental change based on the spectra from Sector 8 is provided by the diverging curves for *Juniperus/Tetraclinis* and pines. Unfortunately, scrub and other companion species of pine and juniper are so scarce and appear so infrequently that it is difficult to assess whether there were changes in the vegetation based on their presence (as they tend to be good ecological markers that are sensitive to any environmental change). The appearance of cedar at the top of the sequence, as well as the appearance of deciduous *Quercus* and the progression of pines, which replace juniper in the anthracological spectra, seems to suggest a noticeable increase in humidity, although in the light of anthracological data we can only affirm that there was a change in the main source of large diameter wood from juniper to pine. It is likely that they both continued to be available in the environment, but a change in the distribution or proportion of these formations could have meant that one species came to be used more than the other.

Other environmental analyses also suggest that the area being studied was sensitive to high- and medium-intensity climate changes that occurred in the late Pleistocene. It was mentioned earlier that previous anthracological analyses in Taforalt had detected different phases characterised by a pronounced decrease in temperature and increase in humidity, to the point that the site was under oro-Mediterranean conditions (cited in Wengler/Vernet 1992). Vernet (1986) estimates that fluctuations in the Taforalt sequence were within a range of 8-9ºC, which would represent a decrease of two bioclimatic zones at the time of the glacial maximum or earlier. Thus, according to the sequence obtained in recent analyses (**fig. 5.3**), the presence of cedar in the charcoal would have coincided with cold events, such as that potentially recorded in YS S8-Y4spit4 (Ward 2007), and later possibly with the Younger Dryas at the top of the Grey Series.

Pollen sequences that are available for the Alboran Sea clearly show alternations between forest (basically *Quercus*) and semi-arid (*Artemisia*, Chenopodiaceae, *Ephedra*) formations, coinciding with increases and decreases in the sea surface temperature, respectively (Dupont 1993; Hooghiemstra et al. 2006; Fletcher/Sánchez Goñi 2008). During the glacial maximum, and up to approximately 14,900 cal BP, there was a strong growth of the aforementioned semi-arid and steppe formations, although the presence of *Quercus* (evergreen and deciduous) confirms that this taxon remained in benign enclaves, as evidenced by its identification in terrestrial records such as that of Taforalt. From this date onwards, there was a rapid growth of Mediterranean *Quercus* forests and a reduction in steppe formations in the mentioned pollen sequences. The Younger Dryas marked a reversal of this trend, with a renewed expansion of semi-desert species, although the decrease in tree pollen was slight. The presence of *Cedrus* during this event would therefore suggest that the montane vegetation of North Africa responded positively to the cooling of the Younger Dryas, as it is particularly abundant at the beginning of this phase (Fletcher/Sánchez Goñi 2008, fig. 4), i.e. these areas would have experienced the drop in temperature but the humidity would not have been affected. However, it is important to stress that the progression of pines at Taforalt began at least 1500 years before the dating available for the upper (*Cedrus*) level of the sequence, meaning that we are dealing with a progressive increase in humidity, culminating in the appearance of cedars, rather than a short-lasting event.

The charcoal found at Taforalt shows an almost complete absence of scrub species that are characteristic at times of decline of forest formations (including Ericaceae). This may be due to the 'invisibility' of these species in the record because, although they were present in the landscape, they were used less, as discussed before.

To summarise, the anthracological records of Taforalt show greater access to forest formations (pines, cedars) at certain points in the sequence, which most probably coincide with a greater expansion of these forests during climatic events, in particular, those when the humidity increased. In this regard, there would be a certain amount of opportunism when gathering wood, meaning that they would use the species that were most accessible from the cave but, within the selection patterns, several vegetative plant organs (pine cones) would also be used to meet different fuel requirements. This pattern would be consistent with observations about the source of other materials found in the cave, which show the use of very local resources for materials related to daily or very frequent needs (which would have included firewood), although more idiosyncratic resources (certain lithic materials or shells) were collected from further afield (Barton et al. 2005; Ward 2007).

5.4 SUPPORTING CEMETERY EVIDENCE (SECTOR 10)

Wood Remains from the Cemetery Area

In the cemetery area of Sector 10, a representative assemblage of charred remains (1810 fragments) has been analysed. They correspond to a total of 20 samples (positions) distributed throughout the cemetery area excavated during the present campaign. Most of the samples correspond to sediment dispersed around the cemetery Sector.

The charcoal analysis has revealed a certain taxonomic richness, as 24 different taxa have been identified (**fig. 5.4**). However, pines and junipers (*Juniperus*/*Tetraclinis*) constitute almost 80 % of the total and are also the most ubiquitous taxa in all the samples. Evergreen *Quercus*, *Acer* and *Salix* are present to a lesser extent; the presence of other taxa is rarer (there are at least 13 species with values < 1 %, corresponding to thermo- and meso-Mediterranean shrub species, including various sclerophyllous shrubs (**fig. 5.4** and **tab. 5.1**). The massive use of coniferous species supports the strong presence of these woodlands in the environment, and the charcoal assemblage provides an image of open formations with some mesophilic taxa, probably relegated to more benign areas or riversides. This image matches the one obtained in Sector 8 for the same chronology (15,000-13,700 cal BP). A sizeable presence of pine cone bracts has also been identified among the fuel remains (approximately 7 % of the pine remains are bracts), which poses the same considerations here as for Sector 8 and supports the existence of a wood gathering pattern that is very similar in every way.

In comparison with the results of Sector 8, it is therefore shown that use was made of the wood that was available (and probably more abundant/accessible in the surroundings), but in the case of charcoal no bias is seen in the selection of species for a specific ritual. However, it is more difficult to assess whether there were species that were not used due to social conventions, as there would be no record of these among the charred remains. In this regard, for example, cedar wood has not been found in the cemetery area, which, given its only very occasional presence in the Sector 8 sequence, is difficult to interpret, one way or the other.

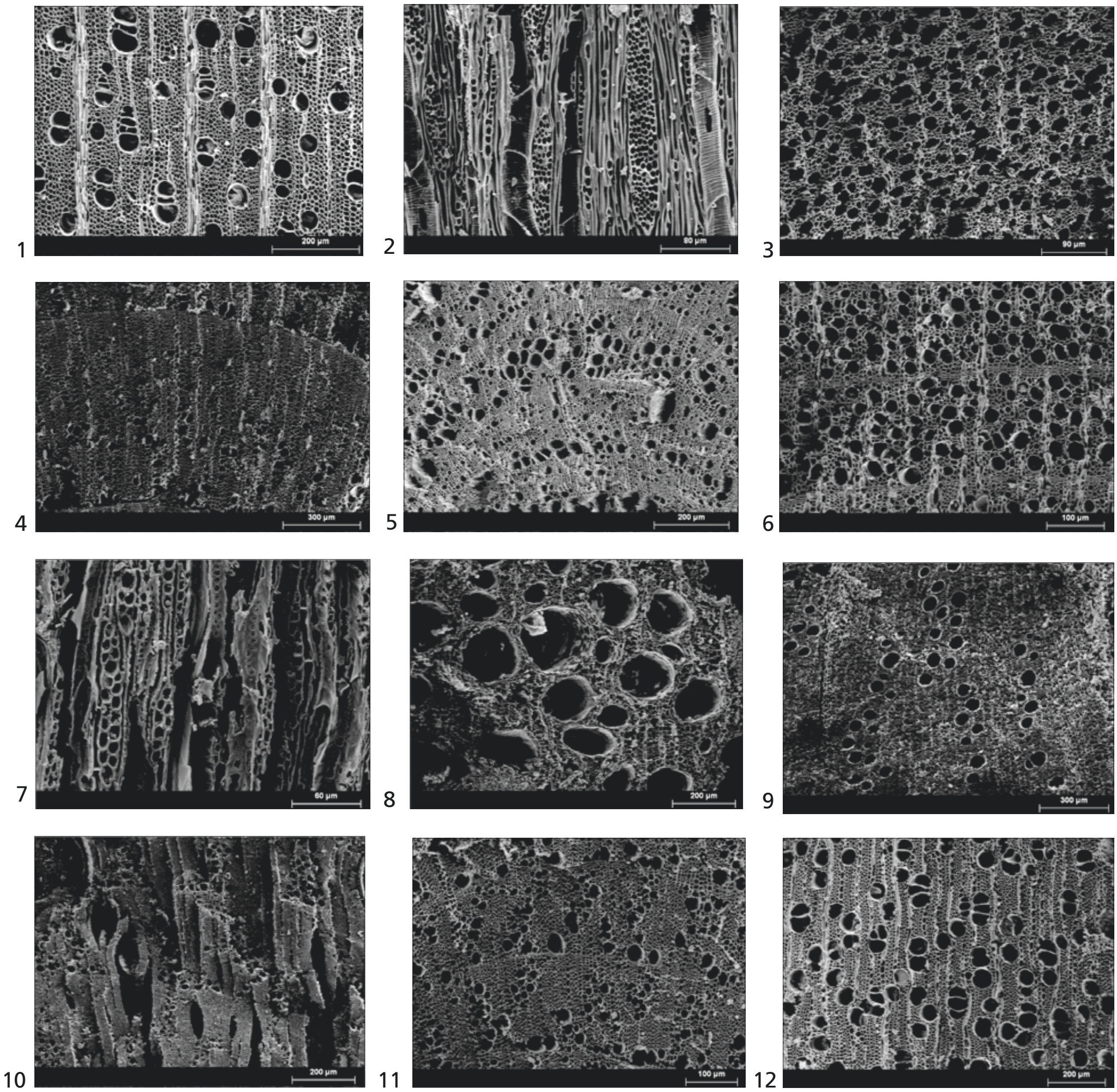

Fig. 5.4 SEM photographs of some taxa identified in Sector 10: **1** *Acer* sp., cross-section x150; **2** *Acer* sp., tangential section x300; **3** Cistacea, cross-section x250; **4** Composita, cross-section x90; **5** Fabacea, cross-section x130; **6** Maloidea, cross-section x200; **7** Maloidea, tangential section x400; **8** *Quercus* sp. deciduous, cross-section x110; **9** *Quercus* sp. evergreen, cross-section x80; **10** *Rhamnus-Phillyrea*, cross-section x110; **11** *Rosmarinus* sp., cross-section x180; **12** *Salix* sp., cross-section x100.

As in Sector 8, heavy use of medium and large sized wood (tree or tall shrub species) is seen in the cemetery area, whereas scrub species are only represented marginally, although there is a wide range of these (fig. 5.4 and tab. 5.1). In other contexts, some authors see this emergence of predominantly tree species as a clear selection of fuel for ritual purposes (Diogo Monteiro et al. 2014), although in the case of Taforalt, we cannot infer a specific practice for funerary contexts based on the fact that this situation also occurred in the other records that were analysed.

<TAF Code> Volume in litres	11020 4	11738 6	11771 7	11773 4	11808 4	11832 1	11843 3	11879 4	11896 6	11940 3	11984 5	12047 6	12084 7	12134 7	12198 7	12264 7	12378 8	12815 3	12954 7	13592 6	Total	
Taxa	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	%
Acer sp.	3			3	5		1	1	3			7	4	1	2	4	6	2	2	9	**53**	**2.93**
Cistaceae			1									1					1				**3**	**0.17**
Compositae											1										**1**	**0.06**
Fabaceae			1			1							1	1		2	1				**7**	**0.39**
Juniperus sp.	58	49	90	35	23	17	19	22	35	21	20	65	40	54	39	58	43	24	29	36	**777**	**42.93**
Labiatae					1				1	2	1	2		1	1	3	3		5		**20**	**1.10**
Monocotyledon												1									**1**	**0.06**
Olea europaea																		1			**1**	**0.06**
Pinus pinaster	10			6	28	7	17	25	12	9	6	17	12	12	14	14	12	38	27	20	**286**	**15.80**
Pinus pinea - P. pinaster	11			2	21	9	10	34	22	8	7	24	18	12	19	28	8	1	2	1	**237**	**13.09**
Pinus sp.	3			1	7		1	4		1	2	13	3	1		7	3	12	16	11	**85**	**4.70**
Pine scale	6	1			1	2	1	2	2	2	1	3	4	1	2	7	1	3	3	3	**45**	**2.49**
Pistacia tp. *lentiscus*						1			1	1		2		1	1		1				**8**	**0.44**
Quercus sp. *deciduous*								1							1	1					**3**	**0.17**
Quercus sp. evergreen			6	3	6	6		9	12	3	6	15	8	9	15	15	9	6	9	11	**148**	**8.18**
Quercus sp.									1			2	1	1	1		3	1			**10**	**0.55**
Rhamnus-Phillyrea			1		1	1			3			1									**7**	**0.39**
Rosaceae/ Maloideae						2			2		1		1							2	**8**	**0.44**
Rosaceae tp. *Rosa*												1									**1**	**0.06**
Rosmarinus officinalis									2			2	1		1	1	1				**8**	**0.44**
Salix sp.	5				5	2	1			1	4	2	5	5	2	5	4				**41**	**2.27**
Tamarix sp.					1			1													**2**	**0.11**
Conifer	2					1										3		7	5	5	**23**	**1.27**
Bark					1					1		1	1			1	3				**8**	**0.44**
Undetermined	2																				**2**	**0.11**
Indeterminable			1			1		1	4	1	1	1	1	1	2	1	1	5	2	2	**25**	**1.38**
Total	**100**	**50**	**100**	**50**	**100**	**50**	**50**	**100**	**100**	**50**	**50**	**160**	**100**	**100**	**100**	**150**	**100**	**100**	**100**	**100**	**1810**	**100**

Tab. 5.1 Frequencies of the taxa identified in Sector 10 (shaded columns correspond to the samples next to a skeleton).

Firewood for Life and Death

One of the most interesting aspects of studying charcoal (and other materials) that appeared in funerary contexts is endeavouring to establish what role it played within the ritual, i. e. what role fire had in the funerary practice and attempting to discern whether it had some kind of symbolic connotation. In any case, the origin and purpose of plant and fire-related remains in these contexts is a complex matter, as its stratigraphic association with human remains is often uncertain.

With regard to the systematic and highly abundant presence of charred wood in the archaeological levels of the cemetery area at Taforalt, which is apparently associated with burials, we are equally uncertain about its use and purpose. *A priori*, there is no evidence of occupation of this sector for anything other than funerary purposes, despite the fact that the systematic presence of disarticulated bones and alteration of the oldest burials suggest that this area was heavily used (Humphrey et al. 2012; Chapter 15). Thus, any remains of the use of fire may be associated with the funerary activities carried out there or elsewhere, remembering, of course, that no *in situ* burning (no hearths or even less formal traces) have been recovered from Sector 10 itself. However, it should not be assumed that fire necessarily formed part of some kind of ritual; it may also be possible that it formed part of more ordinary activities, such as providing heat or lighting while the corpses were being buried. Alternatively, at least some charred material may have been displaced inadvertently, during fill accretion.

The excellent preservation of the charcoal (very angular fragments that are not rounded), as well as its considerable size, are probably due to the specific use of this sector as a cemetery, since the charcoal was not altered by other activities. This state of the charcoal also reveals more or less immediate removal from its original source (fireplaces), and its dispersion could be explained by this movement.

The results of the analysis of charcoal from Sector 10 show that the taxonomic composition of the samples is similar to the spectra obtained in Sector 8 for the same chronology, which appears to rule out any ritual use of selected species and leads us to believe that the inhabitants of the cave systematically used whatever was "closest to hand" in the surrounding area.

Few anthracological analyses have been performed in funerary contexts from the end of the Palaeolithic-Epipalaeolithic. The presence of charred wood remains is frequently mentioned in these analyses but charcoal is often considered merely as a potential element for radiocarbon dating or, in some cases, palaeoenvironmental reconstruction. Therefore, there is still very little discussion about the specific context of these remains within the ritual itself. Studying charcoal morphology or the taxonomic composition of the sample, among other aspects, helps us assess whether or not fire formed part of the funerary ritual. Certain authors have presented the same considerations because, although there are other materials that are clearly a fundamental part of the burial, fires (even *in situ*) are difficult to associate with the deliberate burning of materials that are related to the ritual itself. Comparison with regional analyses of vegetation (pollen and charcoal) makes it possible to infer whether a small number of species were used in relation to a wide range of available resources (Diogo Monteiro et al. 2014) but there are limited records for the area being studied here.

Data from Taforalt's cemetery indicate that, despite the enormous complexity of the ritual carried out (Humphrey et al. 2012), the wood that was used in this area does not differ substantially from that recovered in the outer habitat areas.

5.5 CONCLUSIONS

The anthracological analysis carried out for Taforalt Sectors 8 and 10 returns to some of the questions initially considered by pioneering researchers who first set forth their interest in reconstructing the past landscapes and climate of North Africa by examining plant remains. This interpretative approach has gradually come to include other cultural aspects, such as fuel usage strategies and management of firewood collection areas. In this study we have investigated the use of wood as fuel at the Taforalt site in different areas of daily and symbolic life, since two contexts with a similar chronology (around 15,000 cal BP) could be representative of the domestic and funerary activities that took place in the cave.

The wood taken to the site provides a survey of the composition of the landscape around the cave, since, by gathering wood, the occupants of the cave involuntary 'sampled' the surrounding vegetation. The results suggest that the inhabitants of the cave made use of woody species available in the immediate environs of the cave, probably for various purposes, but principally as fuel for their everyday fires.

Identification of the fuel used indicates that there were coniferous woods in areas that were accessible from the site, in addition to evergreen *Quercus* and other broad-leaved trees such as maples, whereas scrub species are generally scantily represented. The sequence of occupation shows an alternating pattern of vegetation that is characteristic of a more arid climate (in particular *Juniperus*/*Tetraclinis*) and vegetation that grows in sub-humid environments (represented by pines and cedars at the top).

In general, we observed a fuel selection based on availability, abundance and accessibility of wood, with its repeated use in various contexts, as no significant differences were noted between the living area (Sector 8) and the cemetery area (Sector 10) in terms of the range of species used. Furthermore, certain patterns are repeated (preference for medium-large wood diameter, use of pine cones, etc.), suggesting that this wood gathering activity would have followed an established pattern. The considerable presence of a few predominant species certainly leads us to consider the case of plants that may have been present in the landscape but not used as firewood; however, the results include traces of these species (mostly scrub and species that are typical of thermo- and meso-Mediterranean environments) that were relegated to sporadic use only.