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# Holocene forest history of the eastern plateaux in the Segura Mountains (Murcia, southeastern Spain)

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## Abstract

This paper presents a mid- to late-Holocene vegetation sequence of a *Juniperus thurifera*-dominated area in the eastern, continental plateaux of the Segura Mountains of southeastern Spain. A mid-Holocene maximum of mesic tress is recorded in the pollen diagram between c. 6640 and 4790 cal years BP with the vegetation dominated by deciduous oaks. A dramatic decline in deciduous oaks occurred from approximately 4700 cal years BP to be replaced initially by evergreen oak, and then junipers and other xerophytes from c. 4500 cal years BP. This trend of xericness in the vegetation is coherent with regional and extra-regional palaeoclimatic records for increased mid-Holocene aridity. Significant anthropogenic modification of the vegetation occurred in this region from c. 1350 cal years BP represented by a large reduction in all tree taxa (except *Juniperus*) and increases of thorny scrub and nitrophilous assemblages. Increased fire incidence, pastoralism, and arboriculture were associated with this anthropogenic activity. We conclude that present-day *J. thurifera*-dominated communities in this region have become established through a combination of two predominant processes; increased aridification from c.4500 cal years BP and anthropogenic activity from c. 1200 cal years BP.

*Keywords:* Holocene; Quaternary; palaeocology; historical biogeography; palynology; Spain

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## 1. Introduction

Holocene palaeocology has been crucial in demonstrating that historical processes cannot be ignored in contemporary vegetation science (Birks, 1993; Bennett and Willis, 1995). In the Mediterranean Region of Iberia, given the antiquity of human impacts on the landscape, the debate about anthropogenic vs. climatic determinisms has been particularly intense. However, due to the scarcity of suitable sites for pollen analysis, this debate has largely been restricted to the *Quercus*- and *Pinus*-dominated formations (Carrión et al., 2000; Franco et al., 2001), and, to a lesser extent, to the onset of late-

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Holocene forest decline and matorralization (Pantaleón-Cano et al., 2003). Concerning the dynamics of other forest or subforest formations such as those characterized by *Abies pinsapo*, *Tetraclinis articulata*, *Pistacia terebinthus* and *Juniperus thurifera*, little or nothing has been discovered.

Here we present a mid- to late-Holocene vegetation sequence of a *Juniperus thurifera*-dominated area in the eastern, continental plateaux of the Segura Mountains in southeastern Spain. We address the following issues: (1) whether, as in former sequences from the same mountain system, climate has exerted a control on long-term vegetation change or provoked the occurrence of abrupt shifts in timberline vegetation (Carrión et al., 2001a); (2) whether current *J. thurifera* formations are declining (Rivas-Martínez, 1969), or alternatively, they have expanded following late-Holocene aridification (Carrión et al., 2001b), or human activities; (3) whether the history of ecological interactions can be traced back for *Pinus nigra*, *Pinus pinaster*, *J. thurifera*, and *Quercus rotundifolia*, species that compete today in the study area (Sánchez-Gómez and Alcaraz, 1993); and (4) when did modern vegetation become established in the area and what were the processes responsible for its formation?

Apart from the interest of these topics, we have selected this case study because (1) the region was a reservoir of woody species during the last glacial stage (Carrión, 2002; Carrión et al., 2003a), and (2) given its high floristic diversity, endemism, uniqueness of plant associations, and large number of endangered plant species, the eastern Sierras de Segura have been regarded of *community importance* under the auspices of the *Natura Network*, EEC (Sánchez-Gómez et al., 2003). Palaeoecological studies in these sites can provide important long-term data on the processes responsible for the development of this floristically important region. In particular, it can provide crucial information on its vulnerability thresholds to past disturbances, information that is critical for all conservation strategies.

## 2. Physical setting

The study site (2°7′ W, 38°12′ N, 1117 m a.s.l.) is a small intramontane depression (c. 900×250 m), 4.6 km east of the village of El Sabinar ("sabinar" means juniper landscape), within the Benamor river basin on the eastern flanks of the Segura Mountains, northwestern Murcia province, southeastern Spain (Fig. 1). The territory is basically calcareous mountains formed by Cretaceous limestone and dolomite, lying north of Sierra de Revolcadores (2001 m). The depositional context is a massive bed of brown organic clays with sparse basal, angular clasts (c. 1 $cm^3$) grading upwards into a more organic-rich clay.

The site lies in the supramediterranean bioclimatic belt (Fig. 1). Local mean annual temperature and precipitation at this altitude are 11–12 °C and 450–550 mm, respectively. Precipitation is, however, distributed unevenly across the region due to elevational gradients and localized rainshadow effects. Precipitation increases with altitude, often exceeding 600 mm above 1300 m, but dropping below 350 mm along the southern and eastern slopes.

The study basin, which is fed by direct precipitation and surface runoff from the catchment, has been historically drained and cultivated for cereals. The surroundings are characterized by forest patches of *Juniperus thurifera*, and, to a lesser extent, *Pinus nigra* subsp. *clusiana*, *Quercus rotundifolia*, *Pinus pinaster*, and *Pinus halepensis*, with thorny communities of *Berberis hispanica*, *Cytisus reverchonii*, *Juniperus oxycedrus*, and *Erinacea anthyllis*, *Juniperus phoenicea*, and a basal layer of grasses and chamaephytic Lamiaceae. River margins are colonised by *Populus nigra*, *Salix purpurea* subsp. *lambertiana*, *Salix eleagnos* subsp. *angustifolia*, *Salix atrocinerea*, *Ulmus minor*, *Rubus ulmifolius*, and *Rosa micrantha*.

A treeline of *Pinus nigra* occurs throughout the 1600–2100-m zone in the Segura mountains, and correlates with an abrupt change in thermal lapse-rate and wind speed (Valle et al., 1989). Deciduous oak forests prevail on the west and north-west slopes of the Segura Mountains, becoming very rare in the surroundings of the study site. These are dominated by *Quercus faginea*, occasionally accompanied by *Acer granatense* and rarely *Ulmus glabra* and *Taxus baccata*, with relict *Corylus avellana* forests developed in shady valleys. Evergreen *Quercus rotundifolia* forests are frequent below c. 1400 m.

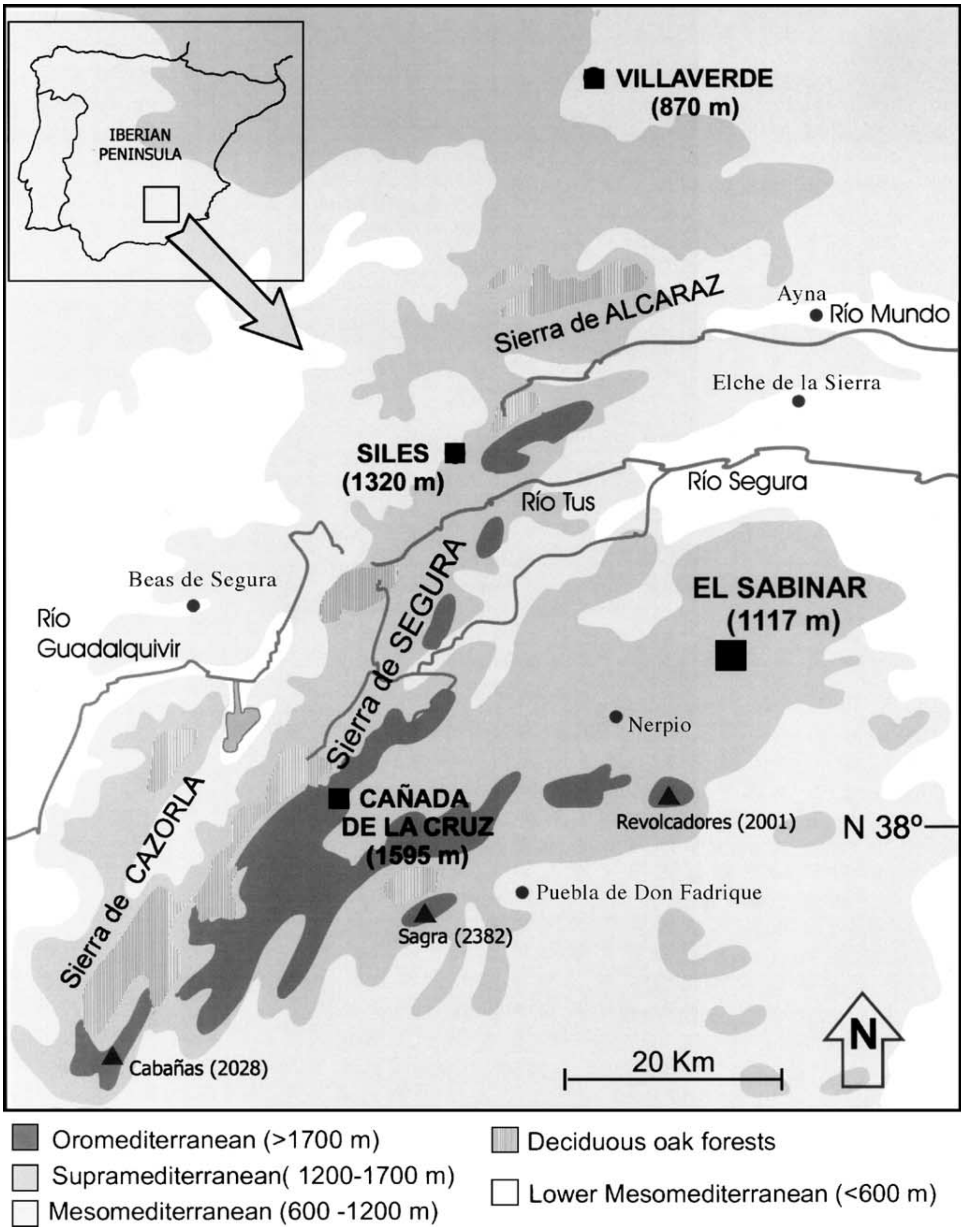

Fig. 1. Location of El Sabinar and other pollen sites in the Segura Mountains of southern Spain. Vegetation belts follow Valle et al. (1989). The study sequence lies within the supramediterranean belt.

Thermophilous *Quercus coccifera*, *Pistacia lentiscus*, and *Phillyrea angustifolia* understorey communities are characteristic of the lower, more xerophytic mesomediterranean belt.

## 3. Methods

A sediment core was collected from a central point in the dry depression using a 6-cm diameter piston

Table 1
Radiocarbon age determinations on bulk sediment from the Sabinar sequence

| Depth (cm) | Laboratory code | $^{14}$C age years BP | Calibrated age, cal years BP (range, 2$\sigma$) | Analysis |
|---|---|---|---|---|
| 0–2 | Pta-8642 | 1350±110 | 1237 (1422–1052) | Conventional |
| 13–14 | Pta-8477 | 1460±60 | 1353 (1423–1283) | Conventional |
| 94–95 | Pta-8471 | 2550±100 | 2420 (2789–2351) | Conventional |
| 100–101 | Pta-8673 | 2620±100 | 2659 (2891–2427) | Conventional |
| 124–125 | Pta-8667 | 3820±50 | 4205 (4526–3885) | Conventional |
| 129–131 | GrA-20794 | 3980±50 | 4416 (4549–4284) | AMS |
| 136–137 | Pta-8678 | 4030±100 | 4539 (4825–4253) | Conventional |
| 141–142 | GrA-20795 | 4250±50 | 4786 (4961–4612) | AMS |
| 168–169 | Pta-8478 | 5860±80 | 6638 (6806–6471) | Conventional |

Calibrations were carried out following Stuiver et al. (1998) (CALIB 4.3). The calibrated age BP was taken as the midpoint of the 95.4% (2$\sigma$) probability interval.

sampler. The core was extruded in the field, wrapped in cling film, and placed in labelled sections of PVC guttering cut lengthways. Given the predominantly minerogenic character of the sediment, subsamples (c. 1–3-cm thick) were taken contiguously in order to obtain sufficient material for pollen and radiocarbon dating analyses. No macrofossil remains were found throughout the sediment core, which, together with the total absence of peaty layers, suggest that organic-matter decomposition and mineralization must have been important throughout the sequence.

Extraction of palynomorphs follows the standard procedure described by Moore et al. (1991). Mineral separation with heavy liquid (density 2.0) was used for all the samples. Exotic *Lycopodium* tablets of a known concentration were added to estimate pollen concentrations. After chemical and physical treatment, between 274 and 525 pollen grains (excluding Poaceae, local hygrophytes, and non-pollen microfossils) were identified under a light microscope using the reference collection of the Laboratory of Palynology at the University of Murcia.

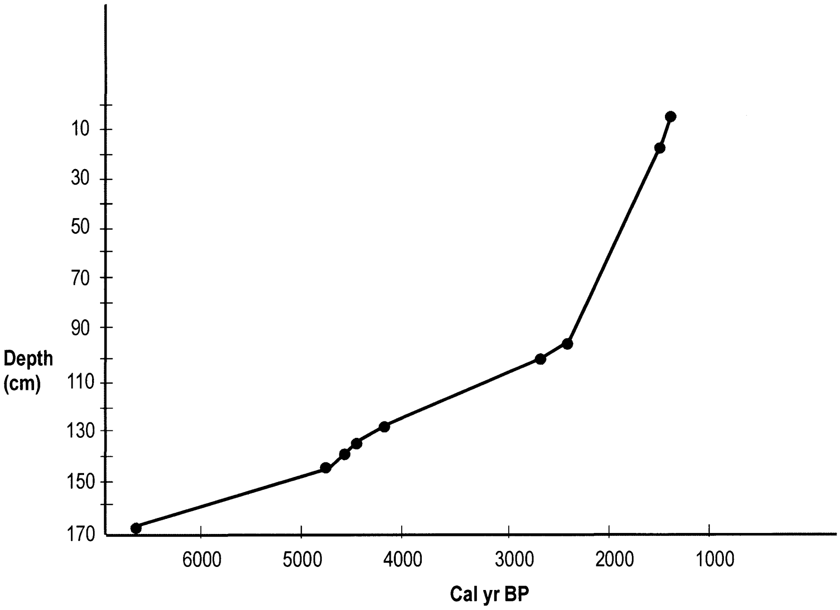

Fig. 2. Sediment depth and radiocarbon age relationship from the Sabinar section.

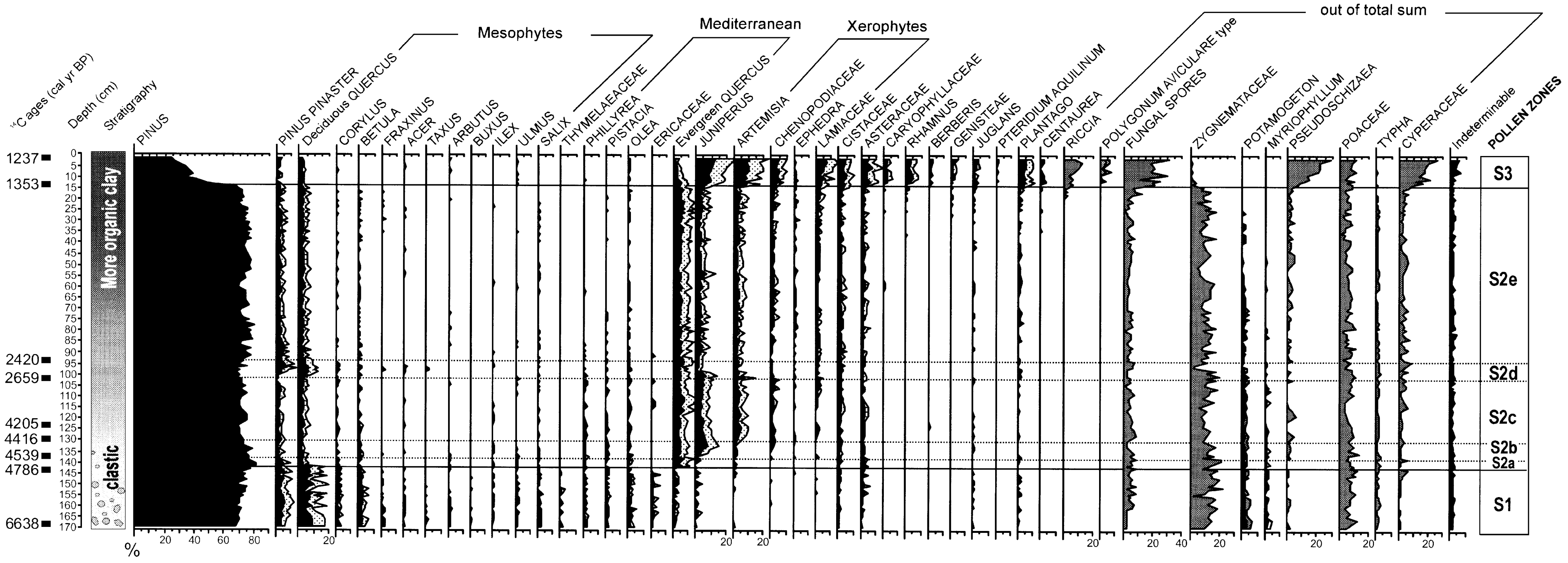

Fig. 3. Percentage pollen diagram of El Sabinar (S). Ages in calibrated radiocarbon years BP (CALIB 4.3, Stuiver et al., 1998).

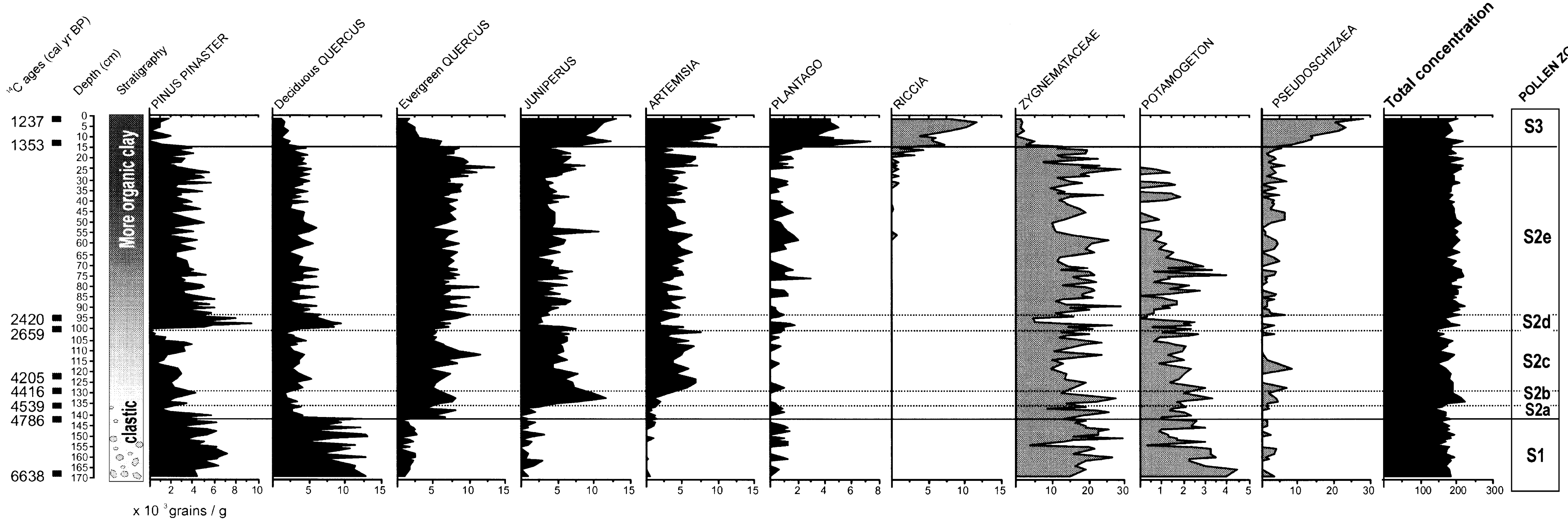

Fig. 4. El Sabinar sequence. Pollen concentration diagram of selected types.

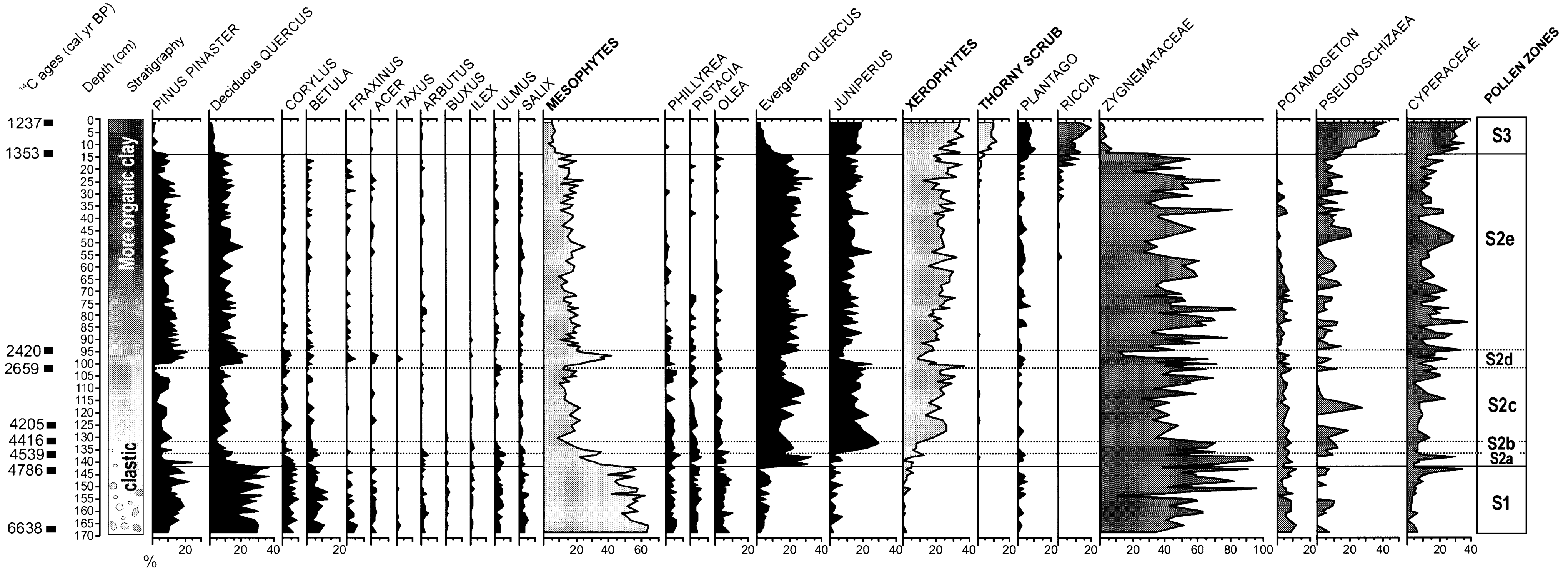

Fig. 5. Synthetic pollen diagram of selected types in the El Sabinar sequence after excluding *Pinus* from the total pollen sum. Ages in calibrated radiocarbon years BP (CALIB 4.3, Stuiver et al., 1998).

Pollen diagrams (Figs. 3–5) were constructed using the computer programs Tilia, TiliaGraph, TGView, and CorelDraw 9.0. The delimitation of percentage pollen zone boundaries was aided by stratigraphically constrained incremental sum-of-squares analysis (Grimm, 1992) using a square-root transformation and chord-distance dissimilarity measure for pollen types that exceeded 2% in any sample, excluding non-pollen palynomorphs and pollen from aquatic and littoral vegetation. The pollen concentration curves for selected taxa (Fig. 4) show similar trends to the percentage curves and support their paleoecological reliability. With the aim of better visualising the variation of the ecologically significant taxa, a synthetic diagram excluding *Pinus* from the pollen sum was constructed (Fig. 5).

## 4. Chronology

The record spans from c. 6640 to 1240 cal years BP. The chronology was established on the basis of nine radiocarbon dates. Samples consisted of bulk organic sediment and were dated by the AMS method where necessary because of the low carbon content of the organic extracts (Table 1). Dates were calibrated using CALIB 4.3 (Stuiver et al., 1998). Calibrated ages BP were taken as the midpoint of the 95.4% ($2\sigma$) probability interval. An age–depth model was based on interpolated ages between adjacent pairs of dates (Fig. 2).

## 5. Pollen stratigraphy and vegetation history

The pollen sequence provides insights into the vegetation history of the supramediterranean areas of eastern Sierras de Segura from c. 6640 cal years BP to c. 1240 cal years BP (Figs. 3–5). Unfortunately, no detailed studies of the present day pollen rain of the area have been made but if the location of the basin and its altitude and diameter are taken into account, the expected pollen source area should include not only the adjacent valley, mostly dominated today by juniper woodlands, but also the surrounding hills with *Pinus nigra*, *Quercus rotundifolia*, and *Pinus pinaster*, the eastern slopes of the highest Segura mountains, and the semi-arid southeastern areas of Murcia.

### *5.1. Mid-Holocene maximum of mesic trees (6640–4790 cal years BP)*

Although there is a predominance of pine pollen, zone S1 (c. 6640–4790 cal years BP) shows the maximum abundance and diversity of mesic trees such as deciduous *Quercus*, *Corylus*, *Betula*, *Fraxinus*, *Acer*, *Ulmus*, *Salix*, and *Taxus*, several Mediterranean taxa (*Arbutus*, *Pinus pinaster*, *Olea*, *Phillyrea*, *Pistacia*) and other pollen taxa such as *Buxus*, *Ilex*, Thymelaeaceae, and Ericaceae (cf. *Erica arborea*) (Fig. 3). Low records occur for evergreen *Quercus*, *Juniperus*, and xerophytes (*Artemisia*, Chenopodiaceae, *Ephedra*).

Based on the current ecology of Iberian species, *Pinus nigra*, *Pinus halepensis*, *Quercus faginea*, and *Quercus rotundifolia* are, respectively, the most likely pine and oak-pollen producing species at these altitudes in the calcareous eastern Betics (Carrión et al., 2001a), although some contribution from *Quercus pyrenaica* growing on siliceous outcrops is also possible. The relatively high amounts of *Typha*, *Potamogeton*, and *Myriophyllum* pollen, and of Zygnemataceae spores suggest the existence of a semi-permanent body of shallow water (Fig. 3).

### *5.2. Decline of deciduous oaks and spread of evergreen oaks and xerophytes (c. 4790–1350 cal years BP)*

During the zone S2 (c. 4790–1350 cal years BP), pine forests continue to be the dominant local vegetation although there is a general decline of deciduous trees, *Pistacia*, *Olea*, and *Phillyrea*, and the disappearance of *Buxus* and Thymelaeaceae. The mesophytic depletion is, in fact, a tendency observed throughout the former zone (Fig. 5). Other taxa increase noticeably such as evergreen *Quercus*, *Juniperus*, *Artemisia*, Chenopodiaceae, *Ephedra*, Lamiaceae, and Cistaceae.

The basal subzones S2a, S2b, and S2c mark the onsets of evergreen oaks (4790 cal years BP), *Juniperus* (4540 cal years BP) and *Artemisia* (4420 cal years BP) spreads, respectively. The subzone S2d (c. 2660–2420 cal years BP) is characterized by slight synchronous increases of *Pinus pinaster*, deciduous *Quercus*, *Corylus*, *Fraxinus*, *Acer*, and *Taxus*. This subzone also shows the intermittent presence of *Juniperus* and *Artemisia*. Limnological conditions are similar to the former zone S1, but *Potamogeton* and *Myriophyllum* become progressively less frequent across S2e, while *Plantago* and *Pseudoschizaea* occur more continuously.

### *5.3. Forest decline and anthropogenic vegetation (c. 1350–1240 cal years BP)*

Progressively during S3 (c. 1350–1240 cal years BP), pine and oak pollen decrease, while *Juniperus*, *Artemisia*, Chenopodiaceae, Lamiaceae, and Cistaceae become more frequent, showing maxima at c. 1240 cal years BP. Several woody taxa (*Betula*, *Fraxinus*, *Taxus*, *Ilex*, *Pistacia*, Ericaceae) disappear from the pollen record. This zone also shows increase of thorny scrub (*Rhamnus*, *Berberis*, Genisteae), nitrophilous assemblages (*Plantago*, *Polygonum aviculare*, Asteraceae, and *Centaurea*), and even indicators of fire (*Pteridium aquilinum*, Genisteae). The increases of walnut (*Juglans regia*) pollen during the zone S3 suggest arboriculture in the region. However, this pollen taxon is recorded throughout the entire sequence of El Sabinar, and since c. 7000 cal years BP in the Siles sequence (Carrión, 2002). These finds favour the hypothesis of natural occurrence, outlined in previous studies in the western Mediterranean (Carrión and Sánchez-Gómez, 1992).

Formation of the current shrubby communities composed of *Berberis hispanica* with *Rhamnus saxatilis*, spiny legumes (*Cytisus scoparius* subsp. *reverchonii*, *Genista scorpius*, *Erinacea anthyllis*), labiates (*Rosmarinus officinalis*, *Lavandula latifolia*, *Thymus vulgaris*), nitrophilous composites (*Centaurea boissieri*, *Artemisia campestris* subsp. *glutinosa*), Cistaceae (*Cistus clusii*, *Cistus albidus*), Caryophyllaceae (*Silene legionensis*, *Arenaria grandiflora*), and grasses (*Arrhenatherum murcicum*, *Brachypodium retusum*, *Festuca capillifolia*, *Festuca hystrix*) (Sánchez-Gómez and Alcaraz, 1993) occurred from approximately 1300 cal years BP.

The increases of *Riccia* just before the S2–S3 boundary at c. 1400 cal years BP could suggest pastoralism in the lake catchment (Carrión, 2002), although *Riccia* spores may also simply indicate a reduction in lake level. Desiccation of the lake is also suggested by the decline of Zygnemataceae and *Typha*, the disappearance of *Potamogeton* and *Myriophyllum*, and the increase of Cyperaceae, fungal spores (organic decomposing activity), and *Pseudoschizaea*.

## 6. Discussion

### *6.1. Role of climate on long-term vegetation change*

Several characteristics of the El Sabinar vegetation sequence fit into a scenario of late-Holocene aridification for the western Mediterranean. These are (1) the S2-S3 increases of xerophytes and *Juniperus* from 4400 to 4500 cal years BP onwards, (2) the overall depletion of broad-leaf trees (Fig. 5), and (3) the lake shallowing indicated by increasing *Typha*, Zygnemataceae, *Potamogeton*, and *Myriophyllum* and decreasing Cyperaceae, *Pseudoschizaea* and fungi.

This regional trend of increasing xeric conditions has been well defined in other Iberian and western Mediterranean areas from pollen records (Ritchie, 1984; Yll et al., 1997; Jalut et al., 2000; Pantaleón-Cano et al., 2003), pollen records combined with microfossil indicators of lake shallowing and infilling (Carrión, 2002; Carrión et al., 2003b), and sedimentological, hydrological, and geomorphological data (Fumanal and Dupré, 1986; Julià et al., 1994; Gasse, 2000; Swezey, 2001).

Westwards, in the central Segura cordillera, the late-Holocene aridification trend is equally detectable, while the period from c. 7500 to 5200 cal years BP represents the mesophytic optimum, the xerophytic minimum, the phase of lowest fire activity, and a stage of relatively high lake levels (Carrión, 2002) and formation of sapropels in tufa systems (Carrión et al., 2001b). Notwithstanding these observations, there is a lack of any clear-cut correlation between the Villaverde, Siles, Cañada de la Cruz, and El Sabinar pollen curves (Carrión, 2002), which demonstrates that, as expected from its high spatial complexity, the Segura region has shown a particularly high amount of variability in the responses to climatic change during the Holocene.

The maxima of *Olea*, *Phillyrea*, *Pistacia*, Ericaceae, *Buxus*, and Thymelaeaceae during S1 suggest that this zone could involve not only the humid optimum, but also the phase of lowest climate continentality and highest mean annual temperatures. A mid-Holocene optimum is also noticeable during the period from c. 6850 to 5200 cal years BP in the supramediterranean site of Sierra de Gádor, Almería; in this case, including *Chamaerops*, *Phillyrea*, *Myrtus*, *Maytenus*, *Asparagus*, *Olea*, and *Pistacia* (Carrión et al., 2003b). These findings may be related with a mid-Holocene expansion of the thermomediterranean vegetation belt towards the interior of Murcia, which would be consistent with the present-day relictual presence of small populations of *Myrtus communis*, *Asparagus albus*, *Asparagus horridus*, *Osyris quadripartita*, *Lavatera maritima*, *Smilax aspera*, *Olea europaea* var. *sylvestris*, *Chamaerops humilis*, and *Periploca angustifolia* in mesomediterranean localities in the province (Sánchez-Gómez et al., 2003).

The slight mesophytic expansion during S2d (c. 2660–2420 cal years BP) deserves attention because a change is observed in the sedimentation rate (Fig. 2) and because a similar pollen stage (zone C4) starts at c. 2700 cal years BP in the timberline site of Cañada de la Cruz (Carrión et al., 2001a). However, the mesophytic phase persists here until c. 1300 cal years BP, and new increases of mesic trees are recorded from c. 790 cal years BP to present. It is worth stressing that both El Sabinar S2d and Cañada de la Cruz C4 fall into one of the aridity intervals suggested by Jalut et al. (2000) for the western Mediterranean region. It is therefore unclear whether these biozones reflect any regional climatic change or anomaly. Possibly, deciduous trees may have survived a regionally dry climate in topographically favourable mid- and high-elevation valleys of the Segura Mountains.

### 6.2. Late-Holocene juniper expansion

*Juniperus* is an important pollen contributor at El Sabinar, especially during zones S2 and S3 (Fig. 3). From its present-day local abundance, it appears plausible that *Juniperus thurifera* is the main species involved, but a substantial contribution of *Juniperus phoenicea* cannot be discarded. A relationship between dry climate and *Juniperus* abundance is suggested by the strong correlation between *Juniperus* and xerophytes, and by the fact that *Juniperus* rises as mesophyte pollen drops and vice versa. This seems not to be a strictly local phenomenon, but is also noticeable in Villaverde (Carrión et al., 2001b).

Rivas-Martínez (1969) suggested that the existing *Juniperus thurifera* communities of Iberia are in decline. The data presented here support the former hypothesis of Ceballos (1934) that *J. thurifera* may have increased recently due to a xerothermic trend. Here we add that, at least for northwestern Murcia, the most recent abundance of juniper trees, in this case since c. 1200 cal years BP, is partially the result of human activities. Thus, the alleged "potential" vegetation (*Juniperetum phoeniceo-thuriferae*) (Sánchez-Gómez and Alcaraz, 1993) is rather anthropogenic and does not correspond with the preanthropogenic situation, where pines, probably *Pinus nigra*, were much more abundant within a forested ecosystem.

### 6.3. Ecological indications and interactions between forest species

Compared to the formerly studied sequences of Villaverde, Cañada de la Cruz, and Siles (Fig. 1), El Sabinar shows a more continuous dominance of *Pinus* and less abrupt shifts in the remaining pollen spectra. This may be related to the continental character of El Sabinar and the local landscape. In fact, the association of continental Mediterranean climates and Holocene pine prevalence is clear in other regions of the Iberian Peninsula such as the northern Meseta (Franco et al., 2001), Central System (García-Antón et al., 1997; Franco et al., 1998), southern Meseta (Taylor et al., 1998; Dorado et al., 1999), Iberian Range (Peñalba, 1994; Sánchez-Goñi and Hannon, 1999; Stevenson, 2000), Valle del Ebro (Stevenson et al., 1991; González-Sampériz, 2000), and interior Levante (Dupré and Renault-Miskovsky, 1990; Andrade, 1994; Burjachs et al., 1997; Carrión and Dupré, 1996; Carrión et al., 1999; Yll et al., 2003). However, at local and centennial scales during the late Quaternary, it can be demonstrated that pine forests have often shown resilience, even inertia to climatic variation (Carrión and van Geel, 1999; Carrión et al., 2001b).

The millenial-scale variation of cluster pine (*Pinus pinaster*) in El Sabinar parallels deciduous *Quercus*, although the alteration of peaks for both pollen taxa can often be observed. In the supramediterranean montane site of Siles (1320 m), the cluster pine showed clear competitive interactions with deciduous *Quercus* and *Pinus nigra*, and successional relationships with evergreen *Quercus* (Carrión, 2002). In Cañada de la Cruz (1595 m), *P. pinaster* and *P. nigra* showed positive correlations (Carrión et al., 2001a). In other pollen records, *P. pinaster* increases after fire disturbance (Carrión et al., 2000; Carrión, 2002), which coincides with current ecological studies—fire experiments—in the Alcaraz mountains (Martínez-Sánchez et al., 1996), and elsewhere in the Mediterranean (Carcaillet et al., 1997). In either case, the mesophytic behaviour of *P. pinaster* in El Sabinar agrees with the modern ombrophily of the species in the eastern plateaux of the Segura Mountains (Fig. 3).

In contrast to other regional pollen diagrams (Carrión, 2002), evergreen *Quercus* variation does not correlate with that of *Pistacia*, *Olea*, and *Phillyrea*, being more abundant during zone S2, when those taxa decline (Fig. 3). In the case of *Pistacia*, it is likely that the pollen-producing species is largely the mesophilous *Pistacia terebinthus* rather than the thermophilous *Pistacia lentiscus*. In any case, the increases of evergreen *Quercus* during S2 and S3 are suggestive of localized competitive displacements of *Quercus faginea* by the most continental and xerophytic *Quercus rotundifolia*. Synchronous declines of *Ulmus*, *Salix*, *Corylus*, *Betula*, and *Fraxinus* may also be related to a retraction of mid-Holocene gallery forests associated with the Benamor river basin.

### *6.4. The anthropogenic landscape*

This new sequence supports the view that the scarcity of deciduous trees in southeastern Spain is partly the result of a long-term trend of increasingly xeric conditions that is characteristically recorded in the western Mediterranean since c. 5000–4000 cal years BP. Unfortunately, the pollen sequence is interrupted at c. 1240 cal years BP, and we have no information about environmental changes that occurred thereafter. However, it is clear that the current landscape is ultimately a consequence of human impact, which would have favoured sylvic-pastoral systems such as the *Quercus rotundifolia* and *Juniperus thurifera* dehesas.

In the study area, the anthropogenic landscape may have its origin relatively late, after c. 1400 cal years BP. In high- and mid-elevation areas of the Segura Mountains, human activities could have taken place well before the occurrence of conventional anthopogenic pollen indicators (Carrión, 2002). *Riccia* rises earlier in the oromediterranean Cañada (c. 3700 cal years BP) than in the supramediterranean Siles (c. 2400 cal years BP) and El Sabinar (before c. 1400 cal years BP), probably because extensive pastures are natural above the treeline. In contrast, *Plantago* and other indicators of agriculture and arboriculture, and indicators of forest degradation stages, occur or start to rise first in the pollen record of the lowland Villaverde (c. 2200–1600 cal years BP), then in Siles (c. 1400 cal years BP) and El Sabinar (c. 1353 cal years BP), and finally in Cañada de la Cruz (c. 670 cal years BP) (Carrión, 2002).

Archaeological data from the Neolithic to the Bronze Age suggest that settlement was sparse in the region (Jordán, 1992). Seed and charcoal data are fragmentary and there is no firm evidence concerning the intensification of agriculture before Roman times (Buxó, 1997). Documentary evidence suggests that only in the last centuries did population growth and the improvement of agricultural technologies appear to have caused transformation of forests into croplands at low- and mid-altitudes, although many areas were left uncultivated or reverted to grazing until the present-day, and much of the forested territory was managed exclusively for timber (Merino-Alvarez, 1915). Numerous reports point to an extensive brush and forest cover, including deciduous and mixed forests, in the eastern Sierras de Segura only a century ago (Sánchez-Gómez et al., 1995). Equally noteworthy is the existence of a number of toponyms relative to the occurrence of several woody species in areas where these are rare today. This is the case for *Arbutus unedo*, *Myrtus communis*, *Acer opalus* subsp. *granatense*, *Corylus avellana*, *Pinus nigra*, *Quercus faginea*, *Juglans regia*, *Pinus pinaster*, and *Buxus sempervirens* (Sánchez-Gómez and Alcaraz, 1993).

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