PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

The Bearing of Phyto-Archaeological Evidence on Discussions of Climatic Change over Recent Millennia

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The bearing of phyto-archaeological evidence on discussions of climatic change over recent millennia

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Phyto-archaeological data based on macro-remains studies, especially prehistoric charcoal, provide evidence concerning the changes in western Mediterranean vegetation during the last millennia. Comparisons are based on present vegetation levels as defined by Ozenda. From the last glacial period to the present time, differences between warm and cool vegetation were of about 8 °C in the south of France but less extreme in more southern regions. The late Pleistocene and early Holocene (Late Palaeolithic and part of Mesolithic) were a period of transition with pines and junipers. Then, the late Mesolithic and the early Neolithic are typically periods of good forestation. During the Neolithic period deciduous and holm oaks had a role of varying importance in all the present Mediterranean levels (thermo- meso- and supramediterranean). Man's influence on the vegetation became significant in the middle Neolithic (south of France) or earlier (south of Spain) and may be characterized by plants such as *Buxus sempervirens*, *Quercus ilex*, *Pinus halepensis* and heaths. The Chalcolithic, the Roman period and the Middle Ages are also periods during which Man's influence was important.

Introduction

Just like palynology, macro plant remains allow us to take an ecochronological approach to ancient Mediterranean floras and vegetations. This paper is especially concerned with prehistoric charcoal analysis. During the past 15 years this methodology has given many answers concerning Man's impact on vegetation. Prehistoric charcoal analysis is the study of wood collected by Man. Combustion generally facilitates the long-term conservation of wood. These processes take place in the Mediterranean area because woody vegetation components are abundant and grow either in forests or in various non-sylvatic formations. On the other hand, a large spectrum of taxa, up to 30 or more, is witnessed. This observation and others prove that wood was not selected by Man. Charcoal may be considered more as random samples than as selective collections. However, in for example fire places, there is a low number of taxa because of the short time they are used. Thus charcoal analysis may be considered as a complement of palynology by taking into account ecological and ethnological components of Man's environment. Charcoal analysis may be used to study the past 20 millennia including the development of modern man and the transition from hunting-gathering to agriculture. This time period concerns particularly the last glacial maximum and the post-glacial warming.

Climatic influences on vegetation

Charcoal analysis provides evidence that between 20000 and 11000 years before present (BP) the periglacial vegetation under the latitudes of southern France was very closely related to the present mountain vegetation (Vernet 1973, 1980*a*; Bazile-Robert 1981). The typical taxa

were pines, *Pinus sylvestris*, birch, *Betula verrucosa*, and also *Hippophaë rhamnoides* and *Sambucus racemosa*. During periods characterized by a warmer temperature (dated from 20000, 16000, 13000 BP (Bazile *et al.* 1986)) thermophilous taxa expanded from their refuges. A particular refuge, on the northeastern Pyrenean slope during a cool period of the late glacial, the upper early Dryas dated from about 12000 years BP (Jalut *et al.* 1975) is especially emphasized. During the warm periods vegetation was quite similar to the present mesomediterranean or supramediterranean levels. Temperature variations would be estimated to be 6–8 °C (Vernet 1986*a*) according to the data (Sabatier & Van Campo 1984; CLIMAP 1976). Vegetation of the lower Mediterranean levels were replaced by forest-steppe or preforest communities mainly composed of the pines *Pinus sylvestris* (figure 1).

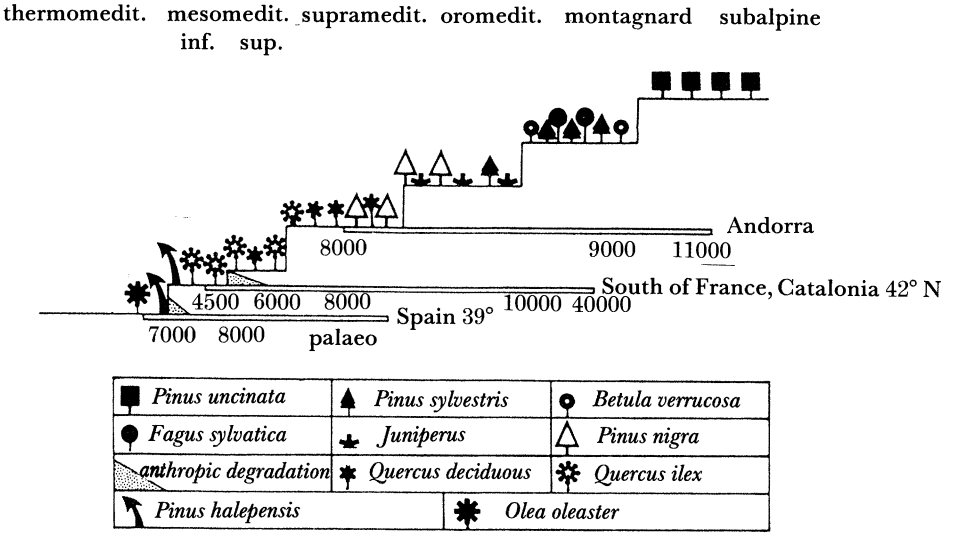

FIGURE 1. Relations between climate and prehistoric vegetation based on present vegetations stages: the double line for Andorra, south of France and Spain, record the change of vegetation and climate from late Palaeolithic to post-Neolithic time (Vernet 1986*b*).

Another important climatic aspect may be deduced from birch ecology. The existence of this species (*Betula* cf. *verrucosa*) at lower levels during the last glacial up to the late glacial indicates moist summers. However, it is difficult to know if summer was the most rainy season. In this case, the climate cannot be assumed to have been Mediterranean. However, from 15000 to 10000 BP (late glacial) thermophilous periods were more frequent. This first transition period is correlated with a progresssive incoming of dry summers. A second transition phase took place between 10000 and 8000 BP with the occurrence of pines, mainly *Pinus sylvestris* and junipers, probably *Juniperus phoenicea*, *J. oxycedrus* and *J. communis*. This phase preceded the establishment of deciduous oak forest (late Mesolithic and early Neolithic) and may be related to oro- or supramediterranean vegetations levels.

This information raises some interesting points.

(i) The decrease and disappearance of birch during the late glacial from lower Mediterranean areas may be correlated with its extension in the regions under oceanic climate since 13000 BP (Van Campo 1984) as a result of the increase in temperature and moisture (change from a continental climate to an oceanic one in non-Mediterranean area). In other

words, the late glacial may be regarded as a time of divergence between the Mediterranean and Atlantic bioclimatic history.

(ii) The oromediterranean *Juniperus* vegetation level has been recognized and exploited by man between 12000 and 8000 BP; the palynological optimum of this plant being generally dated from 13000 to 14000 BP in the south of France (Triat-Laval 1979; Jalut *et al.* 1982). Likewise, the beginning of deciduous oak vegetation (8000 BP) based on charcoal studies is correlated with the palynological dominance of this vegetation.

(iii) Finally, the transition from forest-steppes to deciduous oak forests (the early Holocene post-glacial 'climax') is the last major phytoclimatic division at the 42–44° N latitude. Later, the upper Holocene vegetations record only human influence.

Human impacts on vegetation

Latitudes 43–44° N

Human action on the vegetation is recorded during middle Neolithic with the Chasséens (6000 BP, Vernet & Thiébault 1987). Vegetation opening is characterized by typical indicators such as *Buxus sempervirens* and an increase of *Quercus ilex*. Archaeological data from Dourgne in the Aude basin (Vernet 1980*a*; Guilaine *et al.* 1987) show us that hunting was losing importance in the prehistoric economy, and was being replaced by the breeding of sheep and goats. Later on, especially between 4500 BP and Roman times, breeding and human action on vegetation underwent different degrees of development as a result of Man's interference. Based on these observations we may consider that present 'garrigues' did not appear before the late Neolithic (*ca.* 4500 BP). During the Roman period and the Middle Ages an important change took place. During the first period olive trees and vineyards have taken a decisive role just as at present time, for instance in the Aude plains next to Narbonne, France. During the same period *Pinus halepensis* was increasing with the enlargement of deforested areas. Both beech and fir charcoal have been found in early Middle Ages excavations in alluvial plains. Accurate palynological evidence (Planchais 1982) has recorded beech disappearance after 1300 BP in the Languedoc plain of southern France. Therefore, riverside forests would have been cleared during the Middle Ages, between the tenth and the end of the twelfth centuries. This hypothesis is supported by the history of this period when new soils were constituted along the rivers (Beziers area). These land valorization was facilitated by the diffusion of the 'moulin à paissière' (a type of water-mill). This technique allows systematic irrigation especially in cultivated areas and natural meadows. We must also take into account the development in the making of tools used to cultivate the heavy soils, totally or partly unexploited until this moment.

In Languedoc, the 'silva' was definitely fixed in its major components between the tenth and thirteenth centuries. At this time, last glacial relicts disappeared from plains and a new soil organization was initiated (Durand & Vernet 1987).

Mediterranean area north boundary

The southern thermophilous components such as *Quercus ilex*, are less recorded or absent. At Choranche-Coufin an oak phase is recorded during Mesolithic and early Neolithic. During late Neolithic and posterior times the human activity is mainly revealed by the exploitation of ash. Charcoal ash maximum may be correlated with the occurrence of Bovidae bones (Thiébault

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1983). Foliage exploitation for domestic animals known nowadays in this area had its origin in the Mesolithic. Another feature is the importance of *Taxus baccata* between 5000 and 2000 BP. This species has also been important between 6500 and 5000 BP, as shown by pollen diagrams (Clerc 1985). On the other hand, the data from the Sarrasins cave (Thiébault 1983) reveal the disappearance of *Taxus* and forest exploitation during about 1000 years. The exploitation would be realized in four stages:

(*a*) oak stage with *Fraxinus*, *Taxus*, *Abies*, *Acer* (late Neolithic);

(*b*) ash stage with the decrease of *Taxus*, the disappearance of fir, and the increasing of beech along with *Cytisus laburnum* (Chalcolithic, early Bronze Age);

(*c*) hazel stage with an increase of oak, and the disappearance of yew (middle and late Bronze Age);

(*d*) finally, a new oak stage with *Corylus* and *Fraxinus* is recorded (late Bronze and Iron Ages).

These charcoal stages would reflect a major exploitation from late Neolithic to early Bronze Age followed by a reforestation illustrated by hazel progression during middle and late Bronze Age until the forest's regeneration.

Thermomediteranean level

The northern and central regions of Catalonia in Spain are an area of transition between the charcoal model known for the south of France and more southern arid areas. In the Cova del Frare cave (Ros-Mora 1985; Ros-Mora & Vernet 1987) a post-glacial succession quite similar to the one for the Languedoc has been identified.

On this site a deciduous oak stage (early and late Neolithic) is followed by a *Quercus ilex* stage (Chalcolithic, Bronze Age). Pines (*Pinus halepensis*) were not recorded before early Bronze Age, whereas *Taxus baccata* has a relative importance during Neolithic. This may be related to the particular bioclimatic features of this Iberic Peninsula area.

The present thermomediterranean conditions of the region of Valencia show new sequences. In Cova de l'Or we have recorded an early Neolithic phase with *Quercus ilex* and scarce *Quercus faginea* (Vernet *et al.* 1983, 1987). These results are similar to the displacement observed in the last glacial. Climatic vegetation here is based on *Quercus ilex* formations and not on deciduous oaks, as in northern areas. Therefore, this scheme is more mesomediterranean than supramediterranean. Our conclusions are supported by pollen analysis from Padul at the foot of Sierra Nevada (Pons & Reille 1986). For these authors, the early Holocene climatic vegetation is a 'formation thermophile à *Quercus ilex* et *Pistacia*'. Moreover, wild olive (*Olea europaea* var. *sylvestris*) found in charcoal samples played an important role particularly from about 7500–8000 BP to the present time. In Padul, the beginning of the *Olea* continuous pollinic curve has been dated to 7840 BP (Pons & Reille 1986). Charcoal analysis in Cova de l'Or recorded an increase of olive and the begining of a *Pinus halepensis* curve at about 6800 BP. In Padul the increasing importance of *Pinus* pollens increasing may be related to this scheme. This history can be explained by the increasing human influence.

Pollen analysis and geomorphological studies in cave deposits agree with our results (Fumanal-Garcia & Dupré-Ollivier 1986) particularly with data upon vegetation's degradation. Our results also demonstrate the great importance of *Pinus halepensis* and *Olea europaea* var. *sylvestris* in the middle Neolithic. This evidence was corroborated by the Recambra charcoal diagram (Grau-Almero 1984). Here there is evidence of an early, middle and

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late Neolithic *Pinus halepensis* charcoal stage with *Olea europaea* var. *sylvestris*, scarce *Quercus faginea* and *Pinus nigra*. However, with the study from Recambra the post-Neolithic evolution is acknowledged. During the Chalcolithic and the Bronze Age the *Pinus halepensis* charcoal remains become more scarce and *Quercus faginea* and *Pinus nigra* disappear. These species were replaced by plants from *Rosmarino-Ericion* (for instance heaths as *Erica multiflora*, *Leguminosae*, *Anthyllis cytisoides*, etc.) and *Quercus coccifera*. This history, which culminates in the present vegetation, represents a regressive evolution in contrast to that of the northern boundary, where a cyclic evolution has been recorded.

In thermophilous area in the south of France, particularly in Provence, a progression of *Pinus halepensis* during the early Neolithic has been identified (Vernet 1971, 1980*b*). This evolution is similar to the thermomediterranean model, but may differ in the scarcity or absence of *Quercus ilex* and *Olea sylvestris*. In this area *Quercus pubescens* may be present and abundant both in coast regions and inland.

Conclusions

Charcoal analysis provides evidence of major climatic influences in the vegetation transformation from Palaeolithic to the early Neolithic (table 1). There was probably a decrease of glacial influences with latitude. From the Neolithic on, Man's influence dominates

Table 1. Major events in the prehistoric late glacial and post-glacial south of France vegetation

(Note the climatic determinism before 8000 BP and the increasing of human influence during the past six millennia.)

year (BP)	Age		
			the first ruptures
2000 3000 4000	Iron Bronze Chalcolithic	4	growth of anthropization: regression of deciduous forests,
5000	Neolithic (final) (middle)	3	deciduous forests are cleared extension of green oak and box tree
			adaptations
6000 7000	(ancient) Mesolithic (final)	2	exploitation of deciduous forests no equilibrium rupture growth of deciduous forests
8000 9000	(middle)	1 b	Juniper phase
10000 11000 12000	Epipalaeolithic	1 a	Scots pine phase disappearance of birch in the Mediterranean region

Mediterranean vegetation changes. Middle Neolithic populations were the first responsible for vegetation degradation. Their influence was continued by the populations of the Chalcolithic, Bronze and Iron Ages, Roman and Middle Ages. Lastly, forest potentialities of the Mediterranean area are certainly important in mesomediterranean levels under subhumid climate and in the surrounding mountains. This does not apply to the thermomediterranean semi-arid and arid climates, where the degree of degradation is deeper.

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