

A PRELIMINARY RADIOCARBON DATED POLLEN SEQUENCE FROM THE SERRA DA ESTRELA, PORTUGAL

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INTRODUCTION

The mountains of (sub)oceanic western Europe, west of the range of *Picea abies*, are characterized by a montane forest belt of *Abies alba* and *Fagus sylvatica* and by an upper forest belt of *Fagus*. The tree species at the forest limit is *Fagus sylvatica*, often forming a krummholz. *Fagus* and *Abies* migrated into the mountains roughly 5000 years ago at the end of the Atlantic, replacing deciduous forest elements.

DE VALK (1981) has shown in the Vosges that during late atlantic times a *Corylus* thicket or woodland existed in the present subalpine vegetation belt and that a mixed *Quercus* forest with *Tilia*, *Fraxinus* and *Ulmus* was present in the montane vegetation belt. When *Fagus* migrated into the area the existing plant communities were replaced by *Abies* and *Fagus* but at different velocities. In the montane zone the transition lasted only a few hundred years. In the subalpine zone the replacement by *Fagus* took more than 3000 years.

In view of this it would be interesting to trace the development of mountaineous vegetation in regions where *Fagus sylvatica* and *Abies alba* are absent and where perhaps a few similarities with conditions during the Atlantic of western

Europe might be found. More specifically, a comparison between regions just inside and just outside the natural range of *Fagus* and *Abies* would be useful. The southwestern limit of the range of *Abies alba* is located in the western Pyrénées, that of *Fagus sylvatica* in the Cantabrian mountains of northwestern Spain.

The works of FLORSCHÜTZ (1962) and MENENDEZ AMOR and FLORSCHÜTZ (1961) show that *Fagus* at its western fringe was a very late arrival, less than 2000 years ago. Just like in the mountains of western Europe *Fagus* occurs in the Cantabrian mountains at the tree line (FLORSCHÜTZ, 1961; ERN, 1966). The pollen diagrams suggest that contrary to the Vosges the expansion of *Fagus* took place at the higher altitudes in the mountains, replacing mainly *Quercus*. At any rate much of the development of the forests in these mountains took place without the intervention of *Fagus* and one wonders what the natural zonation of the vegetation would be under these conditions. According to GAUSSEN (1931) a true montane forest does not exist because of the near absence of tree species characteristic for colder climates. Especially the role of *Pinus (sylvestris)* and *Quercus* is interesting in respect to this problem.

Unfortunately much of the natural vegetation of the Iberian peninsula has been severely affected by man who not only depressed the forest line by grazing of cattle but also replaced the native tree species by exotic tree species and by pine. Pollen analysis of cores at various altitudes in the mountains may solve these problems.

The present study concerns a site in the Serra da Estrela (fig. 1), Portugal, thus outside the range of *Fagus sylvatica*. This region was chosen because of its critical position between three main vegetational formations of the Iberian peninsula. Towards the southwest the vegetation is clearly mediterranean in character, towards the northwest lies the very wet atlantic northwestern part of the Iberian peninsula, towards the northeast, east and southeast the vegetation has the character of an arid continental steppe. As a consequence of this position several plant species reach their limit near the Serra da Estrela. The Serra da Estrela is in the western part of the Iberian peninsula at the northwestern limit of *Quercus cocciifera*; at the eastern limit of *Pinus pinea*, *Nerium oleander*,

Olea europea and *Arbutus unedo* and at the northeastern limit of *Cistus monspeliensis* (POLUNIN and SMYTHIES, 1973). Any change in the general climate in the past would affect the location of these boundaries, that in turn may be reflected

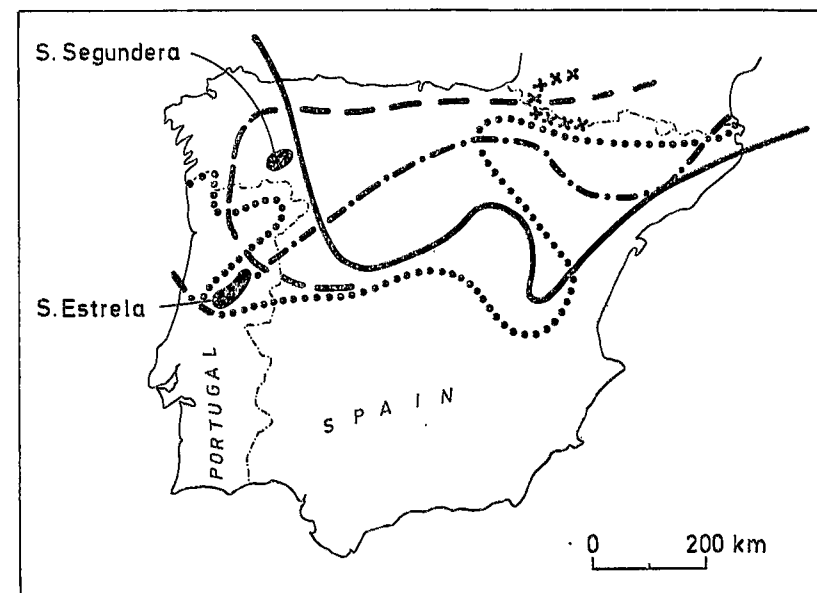


Fig. 1 — Localization of Serra da Estrela and ranges of some important plant taxa.

- southern limit *Fagus sylvatica*
- northern limit *Olea europea*
- northern limit *Quercus cocciifera*
- - - - western and northern limit *Pinus sylvestris*
- x x x x western limit *Abies alba*

in the pollen deposition. The Serra da Estrela is the region in Portugal where as early as 1950 ROMARIZ pioneered in pollen analysis.

GENERAL CHARACTERISTICS OF THE AREA AND LOCATION OF THE CORE

The Serra da Estrela, a hercynic mountain range of granite and schists (DAVEAU, 1969) in central Portugal with altitudes just short of 2000 m (Torre, 1993 m) was glaciated during the Weichselian (DAVEAU, 1971) and thus may offer

opportunities to study cores from lake deposits connected with the glacial geomorphology.

The climate is, due to the position of these mountains, very oceanic. The main plateau receives an average of 2500 mm rain per year (DAVEAU *et al.*, 1977). Around the site the precipitation is less, although still ca. 1600 mm/year.

The present core comes from a small depression at the northern side of Lagoa Comprida around 1600 m altitude (fig. 3). The water level of Lagoa Comprida has been considerably raised by a dam; during periods of high water levels the site is part of the lake. In the past however it is unlikely that this depression had any connection with the lake.

The vegetation of the Serra da Estrela has been described by BRAUN-BLANQUET *et al.* (1952) and DELVOSALLE and DUVIGNEAUD (1962). At lower altitudes the vegetation shows a mediterranean aspect. Generally *Vitis vinifera*, *Olea europaea* and *Castanea sativa* do not exceed 700-750 m altitude, although in favourable places these species grow a few hundred meters higher in altitude. Above 800 m altitude *Secale cereale* is cultivated, occurring up to 1600 m. Below 1300 m fields of *Secale* are accompanied by large areas covered by *Cytisus multiflorus*, *Sarothamnus eriocarpus* and (fires) *Pteridium aquilinum*. Around 1400 m altitude often *Halimium alyssoides* is abundant. Natural forests are very rare, because of heavy grazing by sheep and goats and because large stretches in the montane vegetation belt have been planted by *Pinus pinaster*. Fragments of *Quercus pyrenaica* forest and isolated occurrences of this oak species (up to 1500 m altitude) and of *Taxus baccata* are considered witnesses of the original vegetation type. DELVOSALLE and DUVIGNEAUD (1962) are of opinion that the natural limit of *Quercus* is at 1600 m altitude. The site studied is thus located at the presumed limit of *Quercus* and may therefore at a critical altitude to reflect shifts of the tree line in the pollen deposition. Today the area above 1600 m is completely treeless. According to DELVOSALLE and DUVIGNEAUD the absence of a true montane forest is not only due to man's activities but also because of the absence of true montane tree species such as *Fagus* and *Abies*.

From 1100 m altitude on *Juniperus nana* appears, to become dominant above 1600 m. According to BRAUN-BLAN-

QUET *et al.* (1952) there are three main associations at this altitude: the Galioto-Nardetum, the Junipereto-Ericetum aragonensis (Nardetalia and Ulicetalia) and the Arenarieto-Cerastietum-ramosissimum (Corynephoretalia).

POLLEN ANALYSIS

The core consisting of limnic sediments below 250 cm, of terrestrial peats between 250-150 cm and again limnic sediments above 150 cm was sampled at 20 cm intervals and the material was subjected to acetolysis for 5 minutes. Slides were mounted in silicone oil 2000 CS without stain.

The pollen diagram (fig. 2) has a pollen sum including the tree species *Pinus*, *Betula*, *Quercus*, *Fraxinus*, *Salix*, *Corylus*, *Alnus*, *Castanea*, *Olea*, *Tilia*, *Ulmus* and shrub and herb pollen from non-marshy habitats. Pollen originating probably from plant species that occurred in the depositional basin (e. g. *Potamogeton* and *Ranunculaceae*) were excluded from the pollen sum. In the diagram these two categories are placed on the left and right side of the column showing the actual number of pollen grains that were included in the pollen sum.

RESULTS AND DISCUSSION

The pollen diagram shows neatly seven pollen zones. *Pinus*, *Betula* and *Quercus* are the dominant pollen types throughout the pollen diagram.

Zone 1 is characterized by dominant pollen of *Pinus (sylvestris)*. The NAP is 20 %, consisting mainly of *Rumex*, *Asteraceae liguliflorae*, *Artemisia* and *Plantago type lanceolata*. Pollen of *Echium*, *Anthemis* type, *Chenopodiaceae*, *Campanulaceae* and *Sanguisorba minor* type support the notion that a dry steppe type of vegetation must have been present.

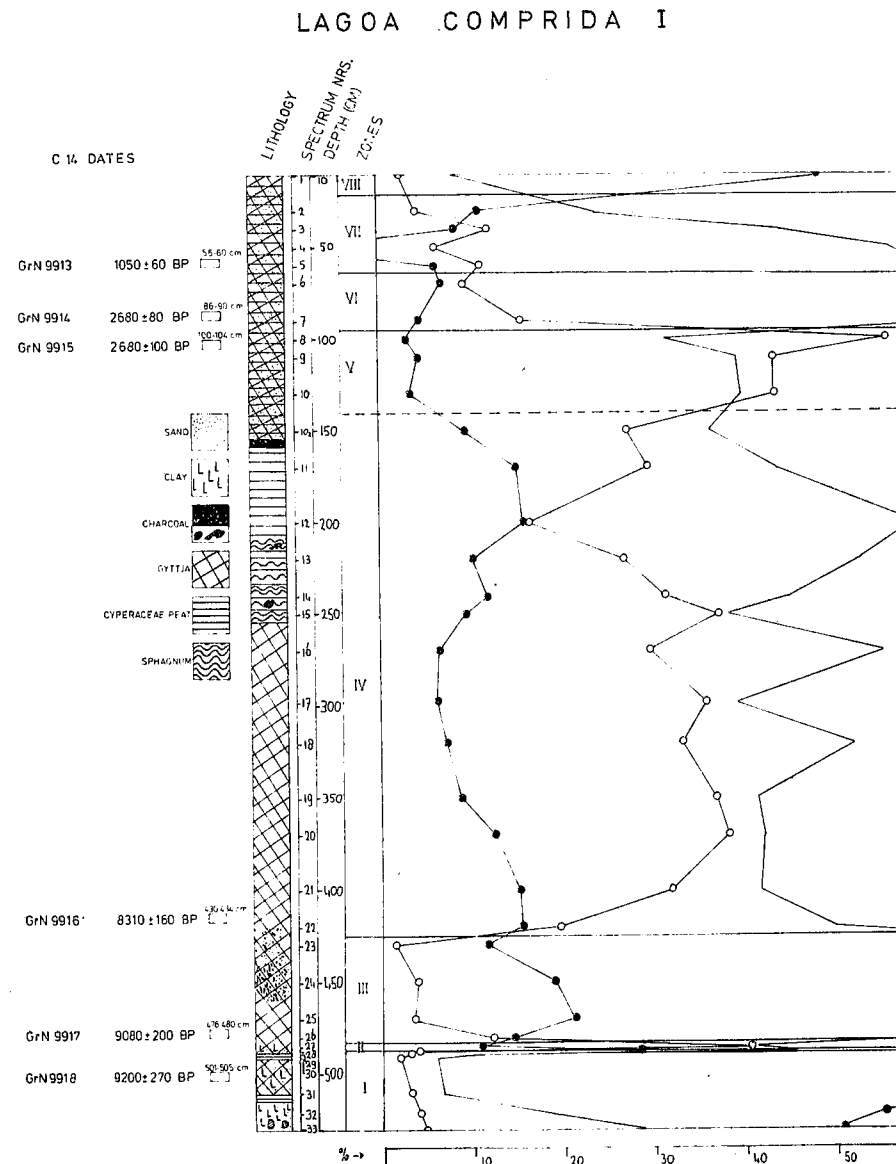
The values of the NAP however are too low (and those of *Pinus* too high) to postulate vast open areas around the site. An open *Pinus* forest may have been present or else the site was near an altitudinal tree limit consisting of pine. Today *Pinus sylvestris* grows up to 2000 m in the mountains of central Spain e. g. the Sierra del Guadarrama (BELLOT

RODRIGUEZ, 1978) and up to 1500 m in the Serra do Gerês (PINTO DA SILVA, oral com.).

An entirely new pollen assemblage is shown in zone III, where the NAP is at a minimum. *Quercus* has become the dominant pollen type, the *Pinus* values have decreased to only 10-20% and the curve of *Fraxinus* has become continuous. This assemblage indicates that the vegetation around the site had the character of a *Quercus* forest. *Pinus*, if present at all, must have been very subordinate in the vegetation.

There is a transitional stage with increased *Betula* values (zone II). Today *Betula (pubescens)* is often a component of the vegetation near the tree line; for instance, in the western Cantabrian mountains there is a narrow belt of *Betula pubescens* on granite at northern expositions, just above a belt of *Fagus sylvatica* (FLORSCHÜTZ, 1962; ERN, 1966). Also the low values of pollen of *Betula* throughout the pollen diagram of the Laguna de las Sanguijuelas (1000 m altitude) and the higher values at the Laguna Arroyas (1600 m altitude) and the Laguna Cardenas (1560 m altitude) in the Serra Segundera (MENENDEZ AMOR and FLORSCHÜTZ, 1961), contribute to the notion that *Betula* was also in the past a more important element at higher altitudes than at lower altitudes in these mountains. *Betula pubescens* is also in the Serra da Estrela a tree species near the tree line. The temporary *Betula* maximum therefore may indicate that the site was, after the more open landscape of zone I, inside or near an upper *Betula* forest belt. A radiocarbon date of the top of zone I is 9200 ± 270 BP (GrN 9918), that of the base of zone III is 9080 ± 200 BP (GrN 9917). The transition thus was very swift, not more than a few hundred years.

This outcome confirms essentially ROMARIZ's (1950) observation from a peatbog near Lagoa Comprida that *Pinus (sylvestris)* pollen is dominant only in the pollen assemblages at the base of the core, whereas it is only a minor constituent in those of the middle part of the peat column. However, we failed to observe the considerable amount of *Taxus* pollen, described by ROMARIZ. At any rate, *Pinus* disappeared already from the Serra da Estrela as an important constituent of the vegetation around 9000 BP and probably never played a role anymore as a montane forest element as it did in the



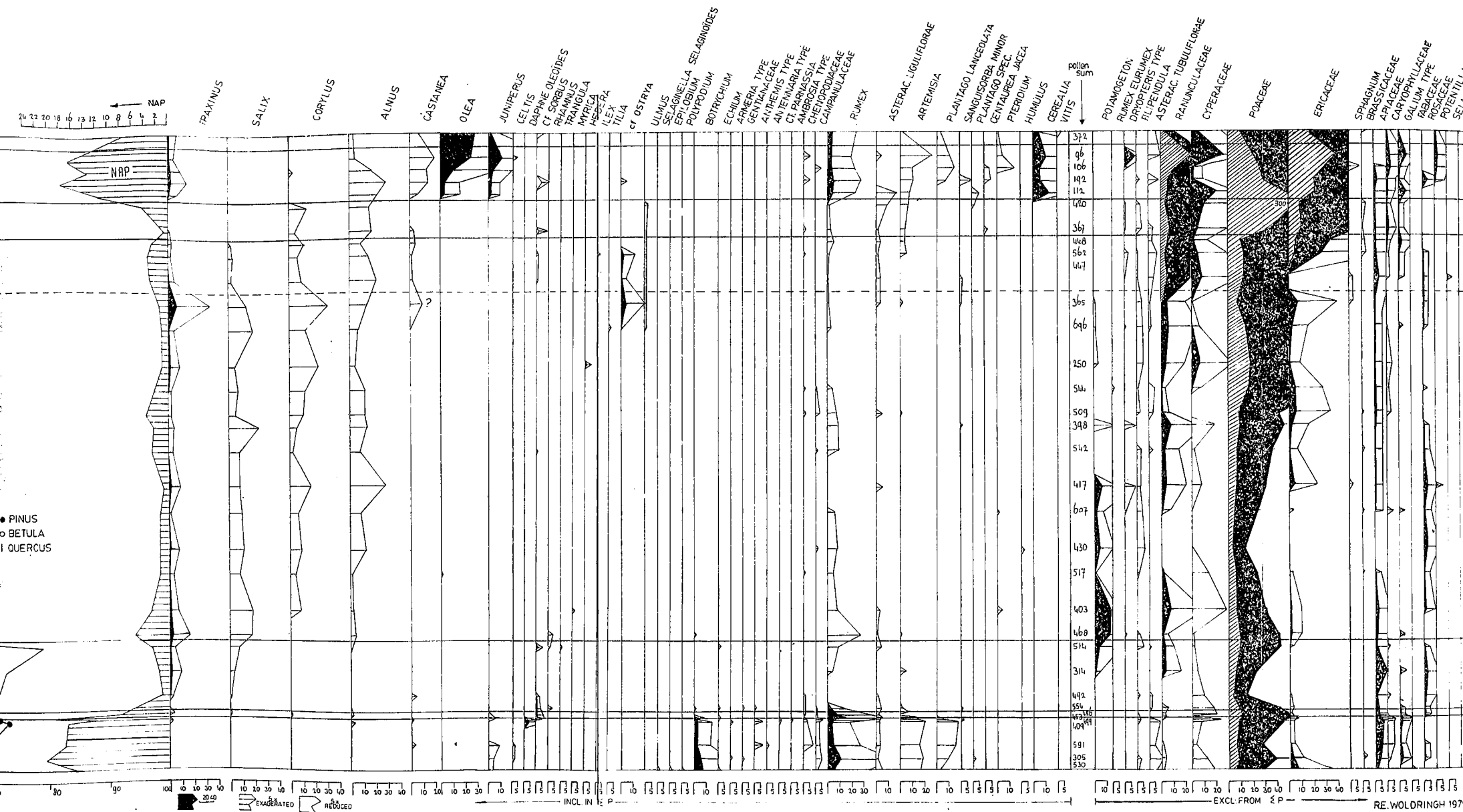


Fig. 2 — Pollen diagram Lagoa Comprida — I.

Sierra de Guadarrama in central Spain (WELTEN, 1956). Isolated occurrences of *Pinus sylvestris* in the Serra do Gerês at the northern border of Portugal and Spain considered by PINTO DA SILVA (1978) and BELLOT RODRIGUEZ (1950) as relics from a once larger range could very well be the descendants from a *Pinus sylvestris* population 9000 years ago.

Zones IV and V are characterized by rather constant values of *Quercus* pollen and fluctuating percentages of pollen of *Pinus* and *Betula* and the appearance of *Corylus* and *Alnus* pollen, the latter probably transported from lower altitudes in the mountains.

A date at the base of zone IV is 8310 ± 160 BP (GrN 9916), that of the top of zone V 2680 ± 100 BP (GrN 9915). Zone IV and zone V thus cover a rather large period of time, ca. 5700 years, in which the changes in the vegetation are comparatively small.

It is difficult to interpret the *Pinus* (showing a minimum of 10 % prior to a maximum of 20 %) and *Betula* fluctuations. The increase of *Betula* at the top of zone V however, may reflect again, as in zone II, the proximity of a tree line. It is however not yet possible to relate these increases in the values of *Betula* with known climatic fluctuations during the Holocene.

In zone VI the pollen assemblage indicates a *Quercus* forest. *Quercus* pollen hovers around 70 %, the NAP is at a minimum and the values for *Betula* have much declined. A radiocarbon date at the base of the zone is 2680 ± 80 BP (GrN 9914) similar to the date at the top of the previous zone. Again thus the transition from a *Betula* zone to a *Quercus* pollen zone is very short living, just like for the transition from zone II/III.

The pollen assemblage of zone VII shows all the features of the influence of man. There are large increases in the values of *Castanea*, *Olea*, *Juniperus*, *Artemisia*, *Plantago lanceolata*, *Pteridium*, *Centaurea jacea* and *Cerealiae*, indicating grazing and cultivation of cereal crops. Around 50 cm depth the samples do not even contain *Pinus* pollen. This absence in the samples is for a pollen type with a large pollen production and good dispersal capacities like *Pinus* very unusual. It may mean that the destruction of the forest was very widespread indeed. Also the near absence of *Corylus* pollen points in the same

direction viz. large scale deforestations at lower altitudes in the mountains.

The radiocarbon date at the base of zone VII is 1050 ± 60 BP (GrN 9913), thus approximately early Medieval time. The topmost sample (zone VIII) shows a large increase of *Pinus*, clearly a reflection of the more recent *Pinus pinaster* plantations at lower altitudes in the Serra and throughout Portugal.

It is tempting to interpret the rise of pollen of the Poaceae, Ericaceae and *Galium* type from zone V upwards as a reflection of the formation of treeless vegetation in the upper reaches of these mountains. However, pollen of Poaceae reaches maximum values in zone VI where the NAP is at a minimum. It is therefore likely that these pollen types came largely from vegetation inside the basin of deposition. Although the same applies for the Ericaceae (*Calluna vulgaris* actually grows today in bog vegetation), there is a steady rise of the values of this pollen type during the time covered by zone VII. Part of the rise of the values of the Ericaceae thus may be connected with man's influence on vegetation.

A comparison with other pollen diagrams from the Iberian peninsula is difficult because of the small number of diagrams and available radiocarbon dates. Towards the north lies at a distance of ca. 220 km the Sierra Segundera where from the Laguna de las Sanguijuelas a radiocarbon dated sequence is available (MENENDEZ AMOR and FLORSCHÜTZ, 1961). The pollen diagram shows steep rises of *Quercus* pollen values at 8160 ± 190 BP (Gro 703) and at 730 ± 80 BP (Gro 698), thus at quite different times than in the Serra da Estrela. Apparently the vegetation development at different altitudes and in the various mountain chains is quite diverse. To trace this diversity is the purpose of future work in the Iberian peninsula.

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RESUMO

Estudo preliminar de um perfil polínico datado a partir do C14, Serra da Estrela, Portugal. O diagrama polínico de um lugar situado a cerca de 1600 m de altitude na Serra da Estrela reflecte a evolução da vegetação, desde uma floresta aberta de pinheiros (*Pinus sylvestris*), anterior a 9200 BP, até uma floresta de carvalhos. Uma curta fase de transição é caracterizada por um máximo de *Betula* que parece indicar a existência de um andar de videiros perto do limite das árvores.

Entre 8300 e 2600 BP existia uma floresta de carvalhos e videiros que se transformou numa floresta de carvalhos, com uma nova fase de transição, caracterizada pela dominância de *Betula*. Cerca de 8000 BP, a aveleira (*Corylus*) e o amieiro (*Alnus*) migraram para a área.

A partir de 1000 BP o diagrama polínico traduz o aspecto desarboreado actual dos andares superiores da montanha, através de um acentuado aumento das percentagens de pólenes de *Juniperus* e *Ericaceae*, e de herbáceas como *Artemisia*, *Rumex*, *Sanguisorba minor*, *Plantago* e *Pteridium*. O pinheiro e a aveleira desapareceram virtualmente e a existência de grandes quantidades de pólen de *Olea europea* e *Castanea sativa* indicam que estes taxa foram cultivados a altitudes mais baixas. Sugere-se que a passagem de uma floresta de carvalhos a uma formação arbustiva de *Juniperus (nana)* resulta de uma utilização excessiva, como pasto, pelo gado.

As amostras da parte superior do perfil polínico mostram um acentuado aumento das percentagens de pólenes de pinheiros, que resulta das actuais plantações de *Pinus pinaster* na montanha.

RÉSUMÉ

Étude préliminaire d'un profil pollinique daté au C14, Serra da Estrela, Portugal. Le diagramme pollinique d'un lieu situé vers 1600 m d'altitude dans la Serra da Estrela reflète l'évolution de la végétation, depuis une forêt claire de pins (*Pinus sylvestris*), avant 9200 BP, vers une forêt de chênes. Une courte phase de transition est marquée par un maximum de *Betula* qui paraît indiquer l'existence d'un étage de bouleaux près de la limite des arbres.

Entre 8300 et 2600 BP existait une forêt de chênes et bouleaux qui se transforma en forêt de chênes, avec à nouveau une phase de transition marquée par la dominance de *Betula*. Vers 8000 BP, le noisetier (*Corylus*) et l'aulne (*Alnus*) s'introduisent dans la région.

Depuis 1000 BP l'assemblage pollinique reflète l'actuel aspect déboisé des parties supérieures de la montagne par un fort accroissement des pourcentages de pollens de *Juniperus* et *Ericaceae* et d'herbacées comme *Artemisia*, *Rumex*, *Sanguisorba minor*, *Plantago* et *Pteridium*. Le pin et le noisetier ont alors virtuellement disparu et de grandes quantités de pollens de *Olea europea* et *Castanea sativa* indiquent que ces taxons étaient cultivés à plus basse altitude. On suggère que le passage de

la forêt de chênes à une formation sans arbres à *Juniperus (nana)* résulte du surpâturage par le bétail.

Les échantillons du sommet du profil montrent un fort accroissement des pourcentages de pollens de pins, résultat évident des actuelles plantations de *Pinus pinaster* à l'étage montagnard.



PL. I — Lagoa Comprida.

(Extr. de A. FERNANDES MARTINS, *O Esforço do Homem na Bacia do Mondego*, Coimbra, 1940. Foto 7, de Humberto Pais).