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New data concerning the evolution of the vegetation in Lillo pinewood (Leon, Spain)

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Abstract. A pollen study of a peat-bog sited in the pinewood of Lillo (León, Spain) is presented. The diagram shows an initial phase where a well-developed pinewood was dominant with deciduous species, followed by a selective clearance process of *Pinus*. Finally, the pinewood recovers again towards a similar state to that described at the beginning of the profile. Radiocarbon dates point that the timing of peat formation took place around 1720 ± 60 years BP and the deforestation on 780 ± 80 years BP. The results have allowed to explain the autochthonous character of Lillo pinewood, which remains as one of the few relics of the southern slopes of the Cantabrian Range.

Key words. Pollen analysis, *Pinus*, Recent Holocene, deforestation, Cantabrian Range, Spain.

Resumen. Se presenta el estudio polínico de una turbera enclavada en el pinar de Lillo (León). El diagrama muestra la presencia de un pinar bien desarrollado acompañado de caducifolios, a continuación un proceso de deforestación mediante tala selectiva de *Pinus*, y finalmente, una recuperación del pinar hacia una situación similar a la inicial de la secuencia. Dataciones mediante radiocarbono han situado el inicio de la secuencia en 1720 ± 60 BP y el de la deforestación en 780 ± 80 BP. Los resultados han permitido esclarecer el carácter autóctono del pinar de Lillo que permanece de forma relíctica como uno de los pocos enclaves en la vertiente meridional de la Cordillera Cantábrica.

Palabras clave. Análisis polínico, *Pinus*, Holoceno reciente, deforestación, Cordillera Cantábrica, España.

INTRODUCTION

Lillo pinewood is located 8 km from the Tarna Pass and belongs to the Puebla de Lillo township (León, Spain). It is the only *Pinus sylvestris* L. mass in the Cantabrian Range, the natural character of which has often been discussed. Though, there are two other enclaves with autochthonous pines (Serra do Gerêz in the North of Portugal and Velilla de Guardo in Palencia) their precariousness however, re-evaluates these results and is of geobotanic interest.

The scarcity of pinewoods in the Cantabrian Range already quoted by Willkomm in 1896, attracted Losa & Montserrat (1953) and Font Quer (1954), who points out the importance of this Leonese pinewood relic. Rivas Martínez (1964) discussed the relationship between the soils and the vegetation in the region of Lillo, interpreting the pinewood as a "paraclimax" adduced to the podsolic soils. He includes it in the *Pinetosum* subassociation of the *Blechno-Fagetum* Tüxen 1958. In the paper mentioned he defends the autochthonous character of the pinewood and points out the presence of mires. The study of these peat sites would allow one 'to solve the problem of the age and authenticity of the pine in this region by making a pollen analysis'.

Since then, a model of potential vegetation in the Spanish phytosociology has been imposed. However, apart from very rare occasions, the pinewoods are never considered as 'vegetation of the terminal ecosystems' (Costa Tenorio *et al.*, 1990). In fact, it is something paradoxical due to the progressive accumulation of numerous pollen data showing the important presence of pines in the Cantabrian Range during the Late-Glacial and great part of the Holocene (Menéndez Amor & Florschütz, 1961, 1963; Hannon, 1985; Watts, 1986). Thus, these works, place the progressive loss of importance and disappearance of the pinewoods in most of the Range, throughout the Holocene. Probably, this reduction of pinewoods initiated by climatic change, was accelerated due to processes of antropic clearance activities (extraction of timber and fires to provide extensive pastures) particularly intense in the latest millenniums (Costa Tenorio *et al.*, 1990). The application of this potential vegetation model culminates with the publishing of the map of the vegetation series of Spain (Rivas Martínez, 1987). Nevertheless, acicular series are not represented in the Cantabrian Range nor the pinewood of Lillo.

Besides, the area contains several North European taxa such as *Equisetum sylvaticum* L. or *Sphagnum magellanicum*

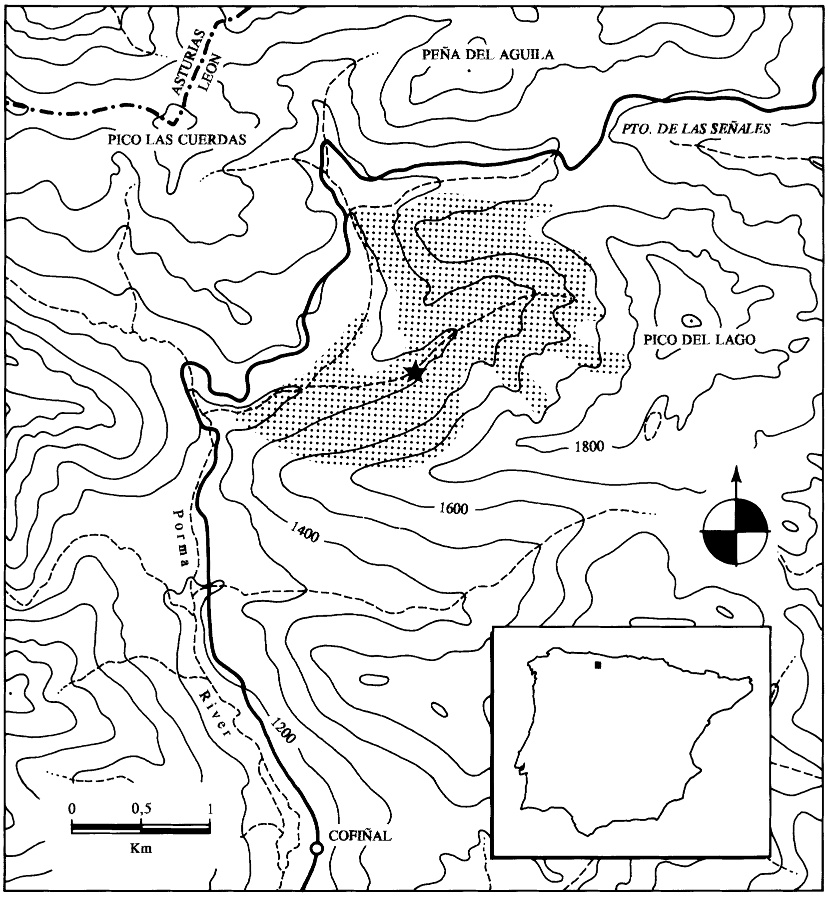

FIG. 1. Location of the peat site.

Brid., which are very rare or absent from the rest of the Iberian Peninsula (Aedo, García Manteca & Martínez García, 1986; Fernández Ordoñez & Simó, 1977). Its presence therefore, provides reasons to consider a natural origin of Lillo pinewood.

In this context, we planned the pollen analysis of samples from mires sited in this peculiar location. Besides, it is the only place in the Cantabrian Range where there are still pinewoods that, although disturbed, maintain a structure, a pyramid of ages and an understorey that can lead us to think of its natural origin.

STUDY AREA

The mire occurs within the so-called 'Lillo pinewood'. This *Pinus sylvestris* woodland is quite well preserved and it is situated in the north facing slopes and head of a stream that flows into the river Porma which rises between the pass of Las Señales (1625 m) and the summit of La Cerra (2007 m) in the southern slope of the Cantabrian Range (Fig. 1).

The mire surface is approximately 300 m^2 and is situated on a plain some metres above the stream at a height of 1360 m. The northern edge of the site is dissected by a pathway that produces some drainage. The dominant species that forms this peat are *Sphagnum recurvum* P. Beauv. and *Sphagnum magellanicum* (Fernández Ordoñez & Simó, 1977).

The climate of the area is montane Atlantic with cold winters and a slight Mediterranean character that is shown through a slight summer draught. Annual precipitation is over 1500 mm and most of this falls as snow which lasts in the north facing slopes for several months.

The pinewood is placed on a substratum formed by Silurian ortocuarcites that have produced oligotrophic soils showing clear signs of leaching. This latter characteristic has been related by some authors to the limited expansion of beech in the pinewood (Rivas Martínez, 1964; Fernández Ordoñez & Simó, 1977). This contrasts with the brown eutrofic soil developed over Carboniferous limestones, which contacts Northwest and Southward with the forest.

The pinewood lies between 1230 and 1700 m of altitude. This vegetal formation reaches a stronger and denser development in the lowlands with deeper soils, where there occur outstanding trees in size and height. The upper limit of the wood shows natural features such as twisted trees of low size effected by wind and snow.

It is a compact formation clearly dominated by *Pinus sylvestris*, although scattered stands of *Fagus sylvatica* L. that may become abundant in areas with better edaphic development can also be found. Similarly, there are scattered oaks (*Quercus petraea* (Mattus.) Liebl.) in rocky stations and patches of birches near mires and other humid areas.

The study nature of the wood enhances the presence of a nemorous understorey in which many species typical of beechwoods and acidophilous birchwoods such as *Vaccinium myrtillus* L., *Saxifraga spathularis* Brot., *Deschampsia flexuosa* (L.) Trin., *Anemone nemorosa* L., *Stellaria holostea* L., etc. can be recognised.

Other arboreal species that appear in the wood are mountain ashes (*Sorbus aria* (L.) Crantz, *Sorbus aucuparia* L.), hazel (*Corylus avellana* L.) and alder (*Alnus glutinosa* (L.) *Geartner*) that occupy the stream banks.

The pinewood surroundings are quite deforested with extensive broom formations and heath. The use of fire used to provide pasture is evident all around the territory, as cattle are still the main source of income for the inhabitants of the region.

MATERIALS AND METHODS

A manual coring has been carried out with a Russian sampler obtaining a core of 2.60 m long. It was subsampled every 5 cm, obtaining forty-three samples. The upper 30 cm were not sampled as it was *Sphagnum* poorly compacted.

The chemical method used for the extraction of pollen and spores from these samples was the traditional chemical technique (Sitter, 1955). *Lycopodium* tablets were added at the earliest stage of the procedure in order to estimate the pollen concentration of each sample (Stockmarr, 1971, 1973).

The arboreal, shrubs and herbs percentages have been calculated starting from the pollen sum in which aquatics, spores and indeterminate grains are excluded. These latter ones are calculated as a percentage of the pollen sum plus their own sum. A total pollen sum that includes the total of all the pollens and spores counted has been also represented (Berglund & Ralska-Jasiewiczowa, 1986).

Lastly, other microfossils such as charcoals, the percentages of which have been calculated starting from the basic sum plus the different non-sporopollinic sums, have been included in the diagram.

The pollen zonation of the diagram has been made by means of a constrained cluster analysis. In order to interpret the temporary variation of the different zones a Detrended Correspondence Analysis (Hill & Gauch, 1980) has been used. In both analyses the taxa present under 5% of the samples have not been taken into account. Neither have been the wide taxonomic groups nor that comprising species of too different environmental requirements. All the computer methods for constructing the pollen diagram have been processed with the TILIA® programme.

RESULTS

A pollen diagram is shown in Fig. 2. All taxa have been represented at the same scale and those with lower values have been exaggerated (shading) five times.

Two radiocarbon dates were carried out at Beta-Analytic Laboratories (Miami, U.S.A.). Both have been calibrated (Stuiver & Pearson, 1986) as Table 1 shows.

The analysed core shows the alternation of two arboreal taxa, *Pinus* and *Betula* throughout the profile. From a quantitative point of view, these two trees mainly form the local forest. Some other taxa such as *Alnus*, *Corylus*, *Fagus*, *Quercus*, *Tilia*, *Ulmus* and *Olea* are also present in this woodland. The whole arboreal pollen reaches values of about 80%. *Fagus* curve increases progressively when deciduous *Quercus* percentage decreases. Though non-arboreal pollen is rich in species, it never reaches significant values except for heather.

The cluster analysis lets us distinguish three local pollen zones divided into seven subzones (Figs 3 and 4). Boundary ages have been estimated according to the calibrated dates:

Zone LIL-1 (255–137.5 cm). Estimated age: 1700–860 years BP

An average *Pinus* and *Betula* values of 45% and low percentages of *Fagus* characterize this zone.

The beginning of this zone is characterized by similar values of *Pinus* and *Betula* (25–30%) and an important percentage of deciduous *Quercus* (15%) in comparison with the upper levels. Heather presents an average value of 14%. The beginning of this period has been radiocarbon dated at 1720 ± 60 years BP (Table 1).

Immediately after, LIL-1b starts with the increase in *Pinus* and the decline in deciduous *Quercus* (8%).

This trend becomes more apparent in LIL-1c where *Pinus* reaches its highest percentage (70%) while *Betula* slightly decreases. *Fagus* becomes more important (6%) when deciduous *Quercus* values decline. By the upper half of this subzone the curves of *Castanea* and *Olea* start.

Another outstanding feature in this zone is the scarcity of charcoal particles.

Zone LIL-2 (137.5–57.5 cm). Estimated age: 860–200 years BP

A sharp decline in *Pinus* and an increase in *Betula* characterize this zone. *Fagus* becomes more important than in the former zone (LIL-1), reaching a value of 14%. The *Juglans* curve, which will be continuous up to the end of the sequence, begins in this period. Heather, herbs and sedges have a notable representation. It has also been divided into three subzones. LIL-2a and LIL-2c are supposed to be transitional phases towards the adjoining zones.

During this transtional phase (LIL-2a) the main feature observed is that of the simultaneous decrease in *Pinus* and increase in *Betula* (40%).

This situation reaches its highest point in LIL-2b, where *Pinus* (4%), which has suffered a sharp decrease, is replaced by *Betula* (56%). Its lower level has been radiocarbon dated at 780 ± 80 years BP (Table 1).

Another transitional phase is again observed towards the upper part of the diagram (LIL-3). It is characterized by a slight increase in *Pinus* (9%). *Betula* decines to percentages similar to those of subzone LIL-2a. Basically, zone LIL-2 has high values of charcoal particles, especially the sample

TABLE 1. Radiocarbon and calibrated dating from Lillo mire. Both dates were carried out on peat sediments.

Laboratory number	Depth (cm)	Uncalibrated dates BP	Calibrated dates BP at two sigma
Beta-67506	115–120	780 ± 80	631–802
Beta-49284	240–255	1720 ± 60	1522–174

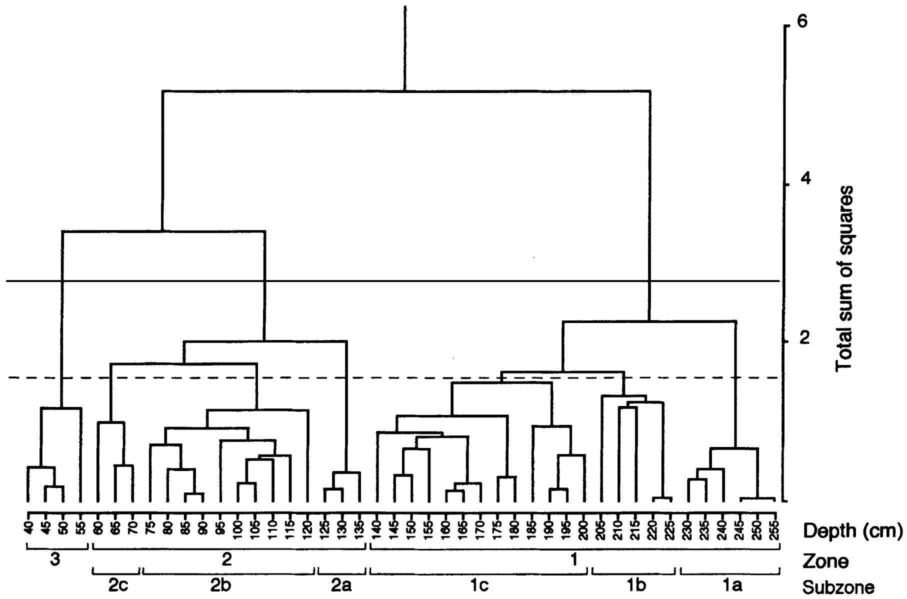

FIG. 3. Total-sum-of-squares dendrogram for the forty-three individual samples of Lillo pinewood. Solid line delimits the local pollen zones and dotted line defines the subzones.

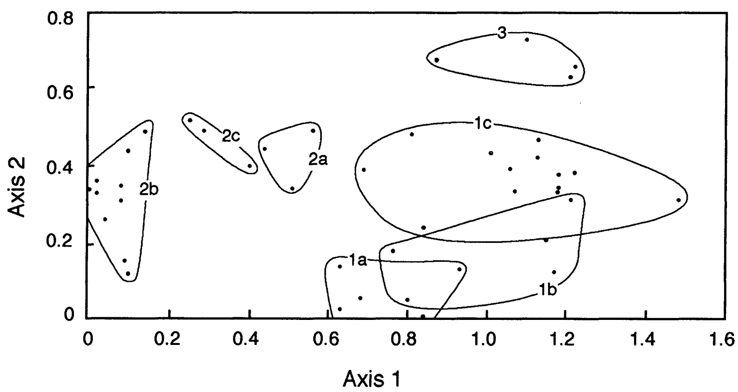

FIG. 4. Plot of the forty-three individual samples on the first and second axes of a detrended correspondence analysis. The samples of each zone have been circled together.

that lies at a depth of 75 cm, at the boundary between subzones LIL-2b and LIL-2c.

Zone LIL-3 (57.5–35 cm). Estimated age: 200–40 years BP

The four last samples included within this zone show an important change with respect to the previous one. Again, *Pinus* values rise to 50% as it happened in zone LIL-1. Likewise, *Betula* ones decrease to 15%. *Fagus* reaches a percentage of 20% when, simultaneously, deciduous *Quercus* decreases.

DISCUSSION

The current presence of Lillo pinewood, considered as a natural piece of vegetation, is completely coherent with the known model of pinewood history in ths Cantabrian Range during the Lateglacial and the Holocene (Menéndez Amor & Florschütz, 1961, 1973; Menéndez Amor, 1968, 1975; Hannon, 1985; Watts, 1986; Aira Rodríguez, 1986; Maldonado, Franco & García-Antón, 1992; Turner & Hannon, 1988). According to these data, cold-tolerant trees as some montane pine and birches should have played an important role in the landscape of this area during the climatic amelioration after the last glacial maximum. In the milder Holocene conditions this species had progressively less importance and its natural area shrank. Probably, the Atlantic was the most unfavourable period for pines. Therefore, *Pinus uncinata* Miller ex Mirbel, which at least reached the mountains of León, Northwestern Spain (Menéndez Amor & Ortega Sada, 1958; Hannon, 1985), disappeared completely in the Cantabrian region and the patches of *Pinus sylvestris* were considerably reduced. Presently, pines are totally absent in the northern slopes of the range and only in southern ones, just as refuges, appear the small patches quoted above, among which the pinewood of Lillo is the most extensive.

Either a direct or indirect human disturbance in the recent reduction in the pine area cannot be forgotten: the frequent use of fire might have destroyed other relics that were in a delicate state due to the adverse climatic conditions. Once vanished, the recovery of these pinewoods is rather difficult due to the presence of more competitive taxa, e.g. beech and oak.

The current vegetation in the surroundings of the site is very alike the one appearing in the diagram, except the disturbance in zone LIL-2. The pinewood with birch and other trees—beech, oak, etc.—surrounded by heaths seems to have lasted, at least, for 1700 years and might have persisted since the lateglacial improvement.

Its persistence might be related to the specific conditions of this site. Steep slopes and rocky soils could have been a barrier against fires. The toughness of the rocks, compact ortocuarcites, has restricted the edafogenetic processes in the slopes and therefore the competence of broadleaf trees (Costa Tenorio, Morla Juaristi & Sainz Ollero, 1988; Costa Tenorio *et al*., 1990). Eventually in the gentler slopes, the maintenance of the pinewood, as Rivas Martínez (1964) pointed out, could be connected with edafic processes, delaying the Holocene forest dynamism on siliceous soils of the Cantabrian Range.

The sharp decrease of *Pinus* in zone LIL-2b cannot be explained by only climatic changes. A slight cooling and rainfall increase could have favoured the rapid birch expansion. Aquatic taxa curves—especially Cyperaceae—might also support some climatic change. Nevertheless, these vegetational changes could most probably be attributed to human disturbance. It could be a selective pine timber that did not affect other trees joined to repeated fires. A significative amount of charcoal particles appears since this zone. The deforestation could not have been aimed at improving grazing because the ground was covered by birch, a pioneering tree. Arboreal pollen values remain similar to the previous ones.

As shown in subzone LIL-2b, the pinewood is not of important significance as a vegetation formation in the landscape of the zone. However, isolated stands or small patches of *Pinus*, remain with a relic character in different parts of the area.

From these residual groupings and individual stands, the pinewood develops extraordinarily towards the end of subzone LIL-2c. Thus, it again becomes a significant piece of vegetation of the landscape in zone 3. This development could also be related to man's attempt to protect and enlarge its area while it continues to recover naturally.

This pine protection by man could have caused the slowing down of beech expansion. The latter, maintains a significant presence in the area throughout subzone LIL-2c and zone 3. In fact, nowadays most of the pinewood located in areas with gentle slopes and valleys is replaced by beech and even by some oaks. The closed forest canopy that produce these broadleaf species inhibited the regeneration of pine. However, in rocky and steep slope biotopes, where there is no danger of competition from broadleaf species, the pinewood, accompanied by birch and a few heliophilous scrubs, retains its natural origin.

In relation to the *Pinus* species that appears in the pollen diagram, there is no doubt that it must be *Pinus sylvestris*. First of all, Scots pine is the only one living in the surroundings. Secondly, Menéndez Amor & Ortega Sada (1958) pointed out that, apart from *P. uncinata*, *P. sylvestris* is the most probable pine that could have lived in the Western Cantabrian Range during the Lateglacial and the Holocene. *P. uncinata* could have hardly lived at an altitude of 1400 m during the Subatlantic period. Finally, *P. sylvestris* wood remains were found in the deepest level of the peatbog (Sánchez Hernando, 1992).

CONCLUSIONS

1. According to the pollen analysis from Lillo pinewood, we consider this piece of woodland to be natural. Undoubtedly, *Pinus sylvestris* is the pine supplying pollen grains to the studied peatbog.

2. The location of this pinewood and weather conditions might explain its preservation as a relic until present-day.

3. The severe reduction of this pinewood between 840 and 200 years BP is probably due to the selective felling of pine trees and the increase in the use of fire.

4. Isolated stands or small patches of *Pinus* remain with a relic character in different parts of the area within this period.

5. The sharp upturn in pine from the quoted relics could be related, at least partially, to human disturbance in historic times. The current stability of the pinewood is ensured on those rocky and step slope biotopes, where it is not endangered due to the broadleaf expansion such as *Fagus* or *Quercus*.

6. The geobotanical and palaeophytogeographical interpretation of this formation fits coherently into the

known pinewood history model in the Cantabrian Range throughout the Holocene.

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REFERENCES

Aedo, C., García Manteca, P. & Martínez García, J. (1986) El pinar de Lillo: un enclave de interés excepcional. *Jornadas sobre la conservación de la naturaleza en España. Libro de comuniaciones*, pp. 297–300. Oviedo.

Aira Rodriquez, M.J. (1986) *Contribución al estudio de suelos fósiles, de montaña y antropógenos de Galicia, por su análisis polínico*. Thesis. Universidad de Santiago de Compostela.

Berglund, B.E. & Ralska-Jasiewiczowa, M. (1986) Pollen analysis and pollen diagrams. *Handbook of Holocene palaeoecology and palaeohydrology* (ed. by B.E. Berglund), pp. 455–484. John Wiley, Chichester.

Costa Tenorio, M., Morla Juaristi, C. & Sainz Ollero, H. (1988) Consideraciones acerca de la evolución del paisaje vegetal de la Península Ibérica en el Cuaternario reciente. *Actes Simposi Inter. Bot. Font i Quer*. **2**, 427–438.

Costa Tenorio, M., Garcia Antón, M., Morla Juaristi, C. & Sainz Ollero, H. (1990) La evolución de los bosques de la Península Ibérica: una interpretación basada en datos paleobiogeográficos. *Ecologia*, fuera de serie **1**, 31–58.

Fernández Ordoñez, C. & Simó, R.M. (1977) Estudio briológico del Pinar de Lillo (León). *Acta Phytotax. Barcinon*. **21**, 43–51.

Font Quer, P. (1954) La vegetación. *Geografía de España y Portugal* (ed. by M. Terán), pp. 145–271. Montaner y Simón, Barcelona.

Hannon, G.E. (1985) *Late Quaternary vegetation of Sanabria March (North west Spain)*. Thesis. Trinity College, Dublin.

Hill, M.O. & Gauch, H.G. (1980) Detrended correspondence analysis: an improved ordination technique. *Vegetatio*, **42**, 47–58.

Losa, M. & Monserrat, P. (1953) Neuva aportación al estudio de la flora de los montes cantabro-leoneses. *Anal. Inst. Bot. Cavanilles*, **11**, 385–462.

Maldonado, J., Franco, F. & García Antón, M. (1992) A new pollen record in Galicia (NW Spain). *Abstracts 8th International Palynological Congress*, Aix-en-Provence. Sep. 6–12 (1992).

Menéndez Amor, J. (1968) Estudio esporo-polínico de una turbera en el valle de la Nava (Burgos). *Bol. R. Soc. Española Hist. Nat. (Geol.)*, **66**, 35–39.

Menéndez Amor, J. (1975) Análisis esporo-polínico de los sedimentos turbosos de los lagos Enol y Ercina. *I Centenario R. Soc. Esp. Hist. Nat. (Geol.)*, 311–313.

Menéndez Amor, J. & Ortega Sada, M.T. (1958) Determinación de las especies de *Pinus* que en los alrededores de Puebla de Sanabria (Zamora) vivieron a lo largo del Tardiglaciar y el Holoceno. *Ann. As. Esp. progr. Ciencias*, **23**, 606–626.

Menéndez Amor, J. & Florschütz, F. (1961) Contribución al conocimiento de la vegetación en España durante el Cuaternario. Resultados del análisis palinológico de algunas series de muestras de turbas, arcillas y otros sedimentos recogidos en los alrededores de: I. Publa de Sanabria (Zamora), II. Buelma (Asturias), Vivero (Galicia) y en Levante. *Est. Geológ*. **17**, 83–99.

Menéndez Amor, J. & Florschütz, F. (1963) Sur les éléments steppiques dans la végétation quaternaire de l'Espagne. *Bol. R. Soc. Esp. Hist. Nat. (Geol.)*, **61**, 121–133.

Rivas Martinez, S. (1964) Relaciones entre los suelos y la vegetación en la comarca de la Puebla de Lillo (León). *Anal. Edaf. Agrobiol*. **23**, 323–333.

Rivas Martinez, S. (1987) *Mapa de series de vegetación de España y memoria*. ICONA. Madrid.

Sánchez Hernando, L.J. (1992) *Identificatión de maderas subfósiles cuaternarias (Holoceno) en las cuencas altas do los ríos Porma y Curueño (León)*. Proyecto fin de carrera, E.T.S. Ing. Montes, Madrid.

Sitter, C. (1955) Méthodes et techniques physiochochimiques de préparation des sediments en vue de leur analyse pollinique. *Rev. I.F.P.*. **10**, 2.

Stockmarr, J. (1971) Tablets with spores used in absolute pollen analysis. *Pollen et spores*. **13**, 15–621.

Stockmarr, J. (1973) Determination of spore concentration with an electronic particle counter. *Danm. Geol. Unders., Arbog*, 1972, 87–89.

Stuiver, M. & Pearson, G.W. (1986) High-Precision calibration of the radiocarbon time scale, AD 1950–500 BC. *Radiocarbon*, **28**, 805–838.

Turner, C. & Hannon, G.E. (1988) Vegetational evidence for Late Quaternary climatic changes in Southwest Europe in relation to the influence of the North Atlantic Ocean. *Phil. Trans. R. Soc. Lond. B*, **318**, 451–485.

Watts, W.A. (1986) Stages of climatic changes from full glacial to Holocene in Northwest Spain, Southern France and Italy: A comparison of the Atlantic coast and the Mediterranean basin. *Current issues in climatic research* (ed. by Ghazi and R. Fontechi), pp. 101–112. D. Reidel, Dordrecht.

Willkomm, M. (1896) *Grundzüge der pflanzenverbrietung auf der iberischen Halbinsel*. Rep. 1976. Verlag. Vaduz.