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Upland vegetation in the north-west Iberian peninsula after the last glaciation: forest history and deforestation dynamics

Castor Muñoz Sobrino[1], **Pablo Ramil-Rego**[1,2] **and Manuel Rodríguez Guitián**[3]

[1] Departamento de Bioloxía Vexetal, Facultade de Farmacia, Campus Sur s/n, E-15706 Santiago de Compostela, Spain
[2] Departamento de Bioloxía Vexetal, Escola Politécnica Superior, Campus Universitario s/n, E-27002 Lugo, Spain
[3] Departamento de Producción Vexetal, Escola Politécnica Superior, Campus Universitario s/n, E-27002 Lugo, Spain

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Abstract. This paper presents the results of pollen analyses from organic sediments of seven cores (299 spectra) in a mountainous area of the north-west Iberian peninsula. The pollen diagrams, supported by seven ^{14}C dates, are used to construct a regional pollen sequence covering the main stages of vegetation dynamics, from the last phases of the Late-glacial until the present. During the Late-glacial Interstadial an important development of cryophilous forests (*Betula* and *Pinus*) was recorded, although various mesophilous and thermophilous tree elements were also present. The Younger Dryas, palynologically clearly defined, is characterized by an important reduction in tree pollen percentages and the expansion of steppe formations (Poaceae and *Artemisia*). At the beginning of the Holocene, there was an expansion of *Quercus* and a spread of other trees, which combined to give a vegetation cover of varied composition but dominated by mixed deciduous forests. Such forest formations prevailed in these mountains until 3000 years ago, when successive deforestation phases are recorded at various times as a result of increased farming activity. The results are compared with data from other mountainous areas in the northern Iberian peninsula and southern France.

Key words: Pollen analysis – Late-glacial – Holocene – Iberian peninsula

Introduction

The mountains of the north-west Iberian peninsula are the present-day distribution limit of many taxa (*Tilia, Ulmus, Fagus,* etc.) and plant communities belonging both to the Mediterranean and Euro-Siberian biogeographical regions (Meusel et al. 1965; Rivas Martínez 1987; Ozenda 1994). The north-west Iberian mountainous area is therefore a link between the main mountain ranges of the north Iberian peninsula (eastern sector of the Cantabrian mountain range, Basque-Cantabrian mountains, Pyrenees, Iberian mountain range, Galician-Duero massifs, Galician-Minho massifs), as well as a barrier between the coastal/sub-coastal sectors and the great interior sedimentary depressions (Fig. 1).

Recent years have seen the publication of various papers analyzing the evolution of the vegetation and climate from the Late-glacial onwards, both in coastal/sub-coastal territories (Ramil-Rego et al. 1994) and in the various montane areas of the Mediterranean: Iberian mountains (Peñalba 1989), Galician-Duero massifs (Maldonado 1994; Allen et al. 1996) and the Euro-Siberian mountains, i.e. the Basque-Cantabrian mountains (Peñalba 1989, 1994). Nevertheless, there is still relatively little information available from the sector's most extensive and complex mountainous area, the Cantabrian mountain range. With the exception of the recent analysis from Lago de Ajo (Allen et al. 1996), the available publications present sequences covering only the Late Holocene, are discontinuous or have serious taphonomic problems, which make them less useful for the reconstruction of changes in the climate and vegetation.

This paper is a palynological study of a mountainous sector situated in the far north-west of the Cantabrian mountain range, i.e. the Ancares mountain range. This biogeographical location enables us to correlate the vegetation development deduced during the last 13 000 years with other pollen sequences from north-west Iberia (Watts 1986; Van Mourik 1986; Ramil-Rego et al. 1993; Maldonado 1994; Ramil-Rego et al. 1994; Allen et al. 1996), as well as with global climatic models based on marine samples (COHMAP 1988; Duplessy et al. 1991). Finally, this information was compared with data from other mountainous areas in south-west Europe such as the Massif Central (Reille et al. 1985), Hautes Alpes (Reille 1990), Pyrenees (Reille 1991; Reille and Andrieu 1991, 1995; Montserrat 1992), Iberian mountain range (Peñalba 1989, 1994; Gómez-Lobo 1993), Basque-Cantabrian mountains (Peñalba 1989, 1994), eastern sector of the Cantabrian mountain range (Muñoz Sobrino et al. 1996) and Serra da Estrela (van den Brink and Janssen 1985; van der Knaap and van Leeuween 1994;

Correspondence to: C. Muñoz Sobrino

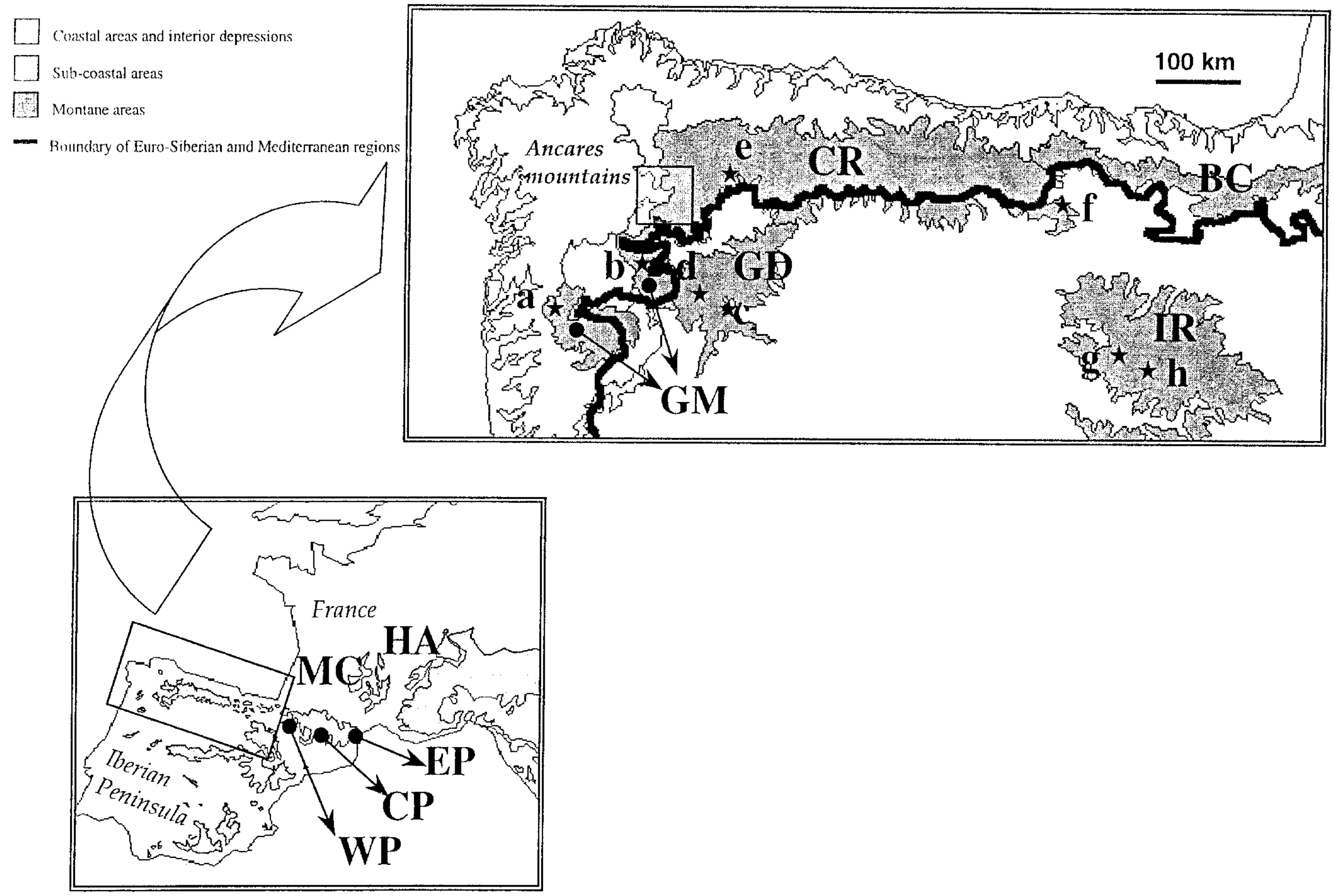

Fig. 1. Map of south-west Europe showing the following: *HA*, Hautes Alpes; *MC*, Massif Central; *EP*, Eastern Pyrenees; *CP*, Central Pyrenees; *WP*, Western Pyrenees; *BC*, Basque-Cantabrian mountains; *CR*, Cantabrian mountain range; *IR*, Iberian mountain range; *GD*, Galician-Duero massifs; *GM*, Galician-Minho massifs
In the map of the north-west Iberian peninsula the following abbreviations are used: *a*, Lagoa de Marinho (Ramil-Rego et al. 1996); *b*, Arroyo de las Lamas (Maldonado 1994); *c*, Sanabria Marsh (Allen et al. 1996); *d*, La Roya (Allen et al. 1996); *e*, Lago de Ajo (Allen et al. 1996); *f*, La Piedra (Muñoz Sobrino et al. 1996); *g*, Quintanar de la Sierra (Peñalba 1989, 1994); *h*, Laguna del Hornillo (Gómez-Lobo 1993)

van der Knaap 1995), and enables us to integrate each of the Ancares (= ANC) regional pollen zones within some of the main phases that have characterized the evolution of the forests in the Atlantic areas of south-west Europe from the Late-glacial onwards (Table 1).

Study area

The Ancares mountains make up part of the western end of the Cantabrian mountain range, north-west Iberian peninsula, and forms a biogeographical limit between the interior depressions of Galicia and the northern Iberian plateau. They extend in a north-east/south-west direction (Figs. 1, 2) with altitudes close to 2000 m. On both sides there are lower mountains that run perpendicular to the main mountain range, which descends towards the river Navia in the western sector and towards the Bierzo depression in the eastern sector.

The bedrock is basically siliceous (quartzites, sandstones, schists, slates, ampelites and granites), with some thin layers of calcareous materials (limestones, dolomites and copper schists). The present morphology of the headwaters and middle ranges of the valleys is the result of glacial and periglacial processes that affected these mountains above an altitude of 800-900 m; in the valley floors and in the glacier scoured basins, wet peaty deposits have often formed, some of which were sampled and analyzed during the course of this study.

Due to their relatively low altitude, in some of these mountains only three of the four bio-climatic zones recognised within the Euro-Siberian region can be recognized (Izco 1987; Table 2). The western slopes are directly exposed to humid oceanic winds which give rise to annual precipitation of over 1400 mm (Rivas-Martínez et al. 1987; Retuerto and Carballeira 1991). However, on the eastern slopes there is less rainfall and greater potential evapotranspiration, so that the atmosphere is more xeric and soils are drier. These factors have a considerable influence on the present vegetation distribution so that optimum Mediterranean formations are present in the south-eastern valleys. The area is widely settled, but it still has considerable expanses of semi-natural forests.

Table 1. Main phases of vegetation development in the Atlantic mountains of south-west Europe since the Late-glacial

	Phase	Characteristics	Period	Chronology (B.P.)
	Ha-2	Crops and afforestation	**Late Holocene**	<1500
	Ha-1	Anthropogenic deforestation. Tree minimum		3500-1500
	Hd-2	Landnam. Expansion of *Betula*-(*Fagus*)	**Middle Holocene**	6000-3500
HOLOCENE	Hd-1	Dominance of *Quercus*-(*Corylus*)		8500-6000
	He-3	(Expansion of *Corylus*)		8500
	He-2	Expansion and dominance of *Quercus*	**Early Holocene**	9500
	He-1	Expansion of *Pinus-Betula*		10 000
	T3	Steppe vegetation: Poaceae - *Artemisia*	**Younger Dryas**	11 000-10 000
LATE-GLACIAL	T2	Mixed forests: *Pinus-Betula-Quercus*	**Lateglacial Interestadial**	13 000-11 000
	T1	Steppe vegetation: *Artemisia*/Poaceae	**Oldest Dryas**	15 000-13 000

With regard to the present vegetation distribution, it is worth highlighting three aspects.

1. The upper limit of forest formations lies at an altitude of between 1450-1650 m on shady slopes and 1550-1750 m on sunny slopes. Above the forest limit, in the subalpine belt, dwarf creeping juniper, *Juniperus communis* subsp. *nana* Willd., and *Vaccinium uliginosum* L., *V. myrtillus* L. and *Calluna vulgaris* (L.) Hull are regarded as representing the climax vegetation.
2. In the forest belt of the Euro-Siberian bio-climate, forests dominated by deciduous tree species are considered to represent the climax vegetation. The mixed deciduous forests include *Betula alba* L., *Acer pseudoplatanus* L., *Sorbus aria* (L.) Crantz, *Sorbus aucuparia* L., *Fraxinus excelsior* L., *Quercus robur* L., *Q. petraea* (Mattuschka) Liebl., *Prunus avium* L., *P. padus* L., *Ulmus glabra* Hudson, *Salix atrocinerea* Brot., *S. capraea* L. and *Fagus sylvatica* L. However, in the eastern sector, on the sunny slopes of the upper colinous and mesomontanous bio-climatic belts, there are particular continental climate features which favour the occurrence of forests of *Quercus pyrenaica* Willd.
3. In the south-eastern valleys, the Euro-Siberian vegetation and Mediterranean formations meet (Table 2), with the latter being mainly represented by supra-

Table 2. Bio-climatic indexes of the zones in the study area

Euro-Siberian Region	Horizon	T	m	M	H	It	P (mm)
Subalpine	Upper	>3°	<-8°	<0°	I-XII	-49 to -10	> 1400
	Lower					-9 to 50	> 1400
Montane	High montane	6 to 12°	-4 to 2°	3 to 10°	IX-VI	51 to 110	>900
	Meso-montane					111 to 180	>900
Colinous	Upper	12°	>2°	>10°	XI to IV	181 to 240	900-1400
	Eucolinous					241 to 310	900-1400
Mediterranean R.	**Horizonte**	**T**	**m**	**M**	**H**	**It**	**P (mm)**
Supra-Mediterranen	Upper	8 to 13°	-4 a-1°	2 to 9°	XI-VI	61 to 110	600-1400
	Middle					111 to 160	600-1400
	Lower					161 to 210	600-1400
Meso-Mediterranean	Upper	13 to 17°	1 to 4°	9 to 14°	X-IV	211 to 260	600-1400
	Middle					261 to 300	600-1400
	Lower					301 to 350	600-1400

T, Average annual temperature; m, average minimum temperature of the coldest month; M, average maximum temperature of the coldest month; H, period of possible frosts (months); It, index of thermal increase; P, average annual precipitation (after Rivas Martínez et al. 1987). It = (T+m+M) x 10, where T = average annual temperature, m = average minimum temperatures of the coldest month; M = average maximum temperatures of the coldest month

Mediterranean forests of *Quercus pyrenaica* and more or less extensive fragments of meso/supra-Mediterranean oak forests. On the western side, there are also some Mediterranean taxa, e.g. *Quercus rotundifolia* Lam., *Q. suber* L., *Fraxinus angustifolia* Valh., *Salix salvifolia* Brot., *Arbutus unedo* L., *Lavandula stoechas* L. subsp. *sampaiana* Rozeira, *Genista falcata* Brot., *Osyris alba* L., *Cystisus multiflorus* (L'Her) Sweet, *Halimium umbellatum* (L.) Spach, *Cistus populifolius* L., etc, within the eucolinous, upper colinous and mesomontanous bio-climatic belt (Rodríguez Guitián and Guitián Rivera 1993).

Material and methods

A total of seven cores from six basins (all bogs, except Pozo do Carballal which is a small lake that sometimes dried out in summer) were analyzed (Fig. 2; Table 3). All samples were obtained with a mechanical hammer drill and kept in a cold-storage room at 5°C before being processed. Samples were prepared for pollen analysis using standard palynolo-gical methods (Fægri et al. 1989; Moore et al. 1991). A total terrestrial pollen sum (>200) was used in calculating percentage representation. Sediment descriptions follow the Troel-Smith system (1955) as modified by Aaby and Berglund (1986).

Conventional radiocarbon dating was carried out in the Centrum vor Isotopen Onderzoek, Groningen University, and in the Rocasolano Institute of Physical Chemistry, National Scientific Research Council, Madrid. Since all of the studied sites are located in areas of silica bedrock the possibility of the dates being affected by the 'hard water effect' can be ruled out (cf. Olsson 1986). In each diagram, local pollen zones were recognized (LPAZs) on the basis of changes in the representation of at least two ecologically significant taxa throughout the sequence (Reille 1990). In some profiles, the LPAZs zones have been subdivided (1a, 1b, etc.) in order to highlight a particular feature within long, rather homogeneous zones.

In a small, well-defined, natural region, changes in vegetation should take place almost synchronously (Reille and Andrieu 1995). Therefore, by analyzing and comparing the different LPAZs, we established a series of equivalences that enabled us to construct a regional pollen sequence (ANC) with ten pollen zones, the interpretation of which can be used to deduce a series of aspects related to the evolution of the vegetation, the environment and the anthropogenic impact since the Late-glacial. Furthermore, this method allows to detect the presence of hiatuses in seemingly homogeneous deposits (Reille 1990).

Table 3. Location of the sampled deposits in the Ancares mountain range

Deposit	Altitude (m)	Latitude	Longitude
Suárbol	1080	42° 51' 50" N	6° 51' 10" W
A Golada	1225	42° 42' 20" N	7° 00' 00" W
Brañas de Lamela	1280	42° 46' 05" N	6° 51' 00" W
Pozo do Carballal	1330	42° 42' 20" N	7° 06' 40" W
A Cespedosa	1425	42° 52' 40" N	6° 49' 50" W
Porto Ancares	1580	42° 52' 00" N	6° 48' 50" W

Results

The pollen diagrams are presented in Figs. 3-9. The sequence from Pozo do Carballal, in which 10 LPAZs are recognised, has the most complete pollen record, i.e. from the Late-glacial Interstadial to the present. It therefore forms the key reference for reconstructing the regional evolution of the region's vegetation. Another two sequences, Suárbol and Brañas de Lamela, also record the end of the Late-glacial period, although both of them have hiatuses throughout the Holocene, which interrupt the pollen sequence at different times. The remainder of the profiles, i.e. A Golada, Porto Ancares, A Cespedosa-I and A Cespedosa-II, have Holocene records only. The characteristics of the different LPAZs and the regional pollen zones (ANC), as well as the correlation of the latter with the most characteristic phases of the dynamics of the vegetation during the Late-glacial and Holocene in the Atlantic mountains of south-west Europe are summarized in Table 4.

Reconstruction of vegetation history and chronology since 13 000 B.P.

1. The Late-glacial Interstadial (RPAZ ANC-1)

In this mountainous sector, the Late-glacial Interstadial represents a development phase of the tree vegetation, although its characteristics differ slightly depending on altitude and location. In the Pozo do Carballal profile (Fig. 3), arboreal pollen (AP) percentages reach values close to 40% and the dominant taxon during this period is *Pinus sylvestris*-type. However, the *Pinus* percentages are smaller than those recorded during the Late-glacial in other more southern sequences such as Lagoa de Marinho (Ramil-Rego et al. 1993), Arroyo de las Lamas (Maldonado 1994), La Roya (Allen et al. 1996) or Sanabria Marsh (Allen et al. 1996).

In the north-western sector of the Ancares mountain range, on the other hand, the sequence from Suárbol (Fig.4) has AP values higher than 60%, with a predominance of deciduous tree pollen and low *Pinus* values. The most abundant taxon is *Betula*, although the presence of other mesophilous species is also recorded such as *Quercus robur*-type, *Corylus* and *Castanea*. The sequence obtained in Brañas de Lamela (Fig. 5) is very similar. The main differences are due to the presence of *Quercus ilex*-type pollen and lower *Corylus* values. This may be due to greater dryness, this area being oriented towards the south and sheltered from humid oceanic winds.

2. The Younger Dryas (RPAZ ANC-2)

In the profiles from the western sector of the Ancares mountain range, Suárbol and Pozo do Carballal (Figs. 4, 3, respectively), there is a noticeable reduction in AP (less than 20%) at the end of the Late-glacial Interstadial, and the mesophilous elements are poorly represented.

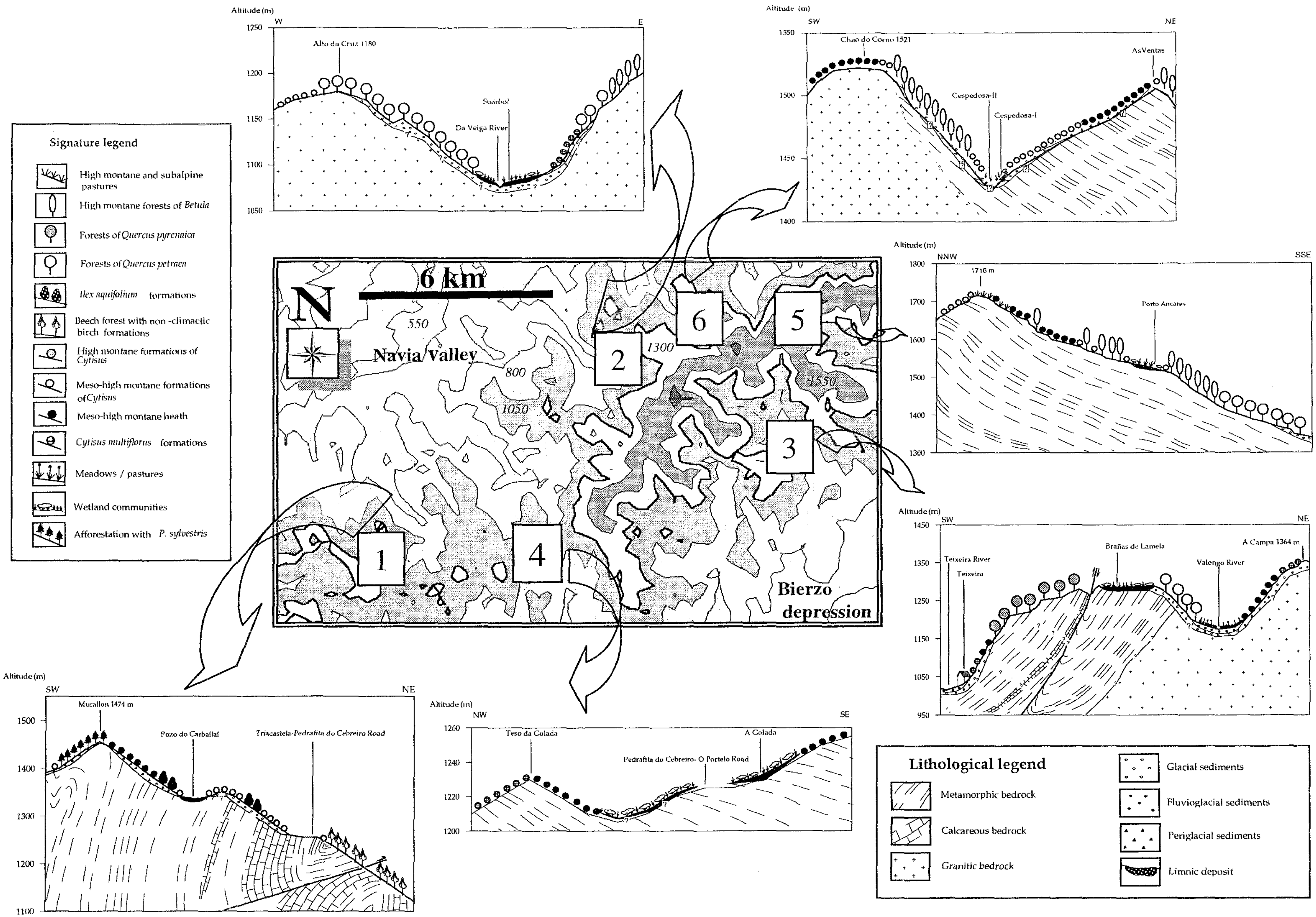

Fig. 2. Map and sketches showing various details of the study sites. In the map, contours are shown in metres

Table 4. Regional zones obtained in the Ancares mountain range, western end of the Cantabrian mountain range

Regional zones		Ancares mountain range								
Phase	ANC	SU	BL	AG	PA	AC-I	AC-II	PC	Pollen characteristics	Chronology
Ha-2	10	10	7-8	4	6		3b-4	10b	Poaceae / Ericaceae (*Pinus*)	
	9	7-9	4b-6	3	5	6-7	3a	10a	Ericacae-Poaceae	
	8				4b	4-5	2	9	*Betula-Quercus*-(Poaceae-Ericaceae)	1250±50 B.P.
Ha-1	7	6	4a		4a	3	1	8	*Poaceae/Ericacae*	2070±25 B.P.
Hd-2	6	5	3	2	3	2		7	*Betula-Quercus* (Poaceae/Ericaceae)	2960±50 B.P. 3090±35 B.P.
	5			1	2	1		6	*Quercus* (*Betula*). First appearences of cereal	3390±40 B.P. 5230±60 B.P.
Hd-1	4b				1			5	*Quercus*	
He-2	4a	4						4	*Quercus-Betula* (Poaceae)	
He-1	3	3						3	*Betula (Pinus)*-Poaceae	10 360±210 B.P.
T3	2	2	2					2	*Poaceae-Artemisia*	
T2	1	1	1					1	*Betula/Pinus* (*Quercus*)	

SU	Suárbol	AG	A Golada	AC-I	A Cespedosa-I	PC	Pozo do Carballal
BL	Brañas de Lamela	PA	Porto Ancares	AC-II	A Cespedosa-II		Fibrous peat
			Clayey sediment		Humified peat		

Poaceae is the dominant taxon, while *Artemisia*, Chenopodiaceae, Liguliflorae and Tubuliflorae are less abundant. On the other hand, in the diagram of Brañas de Lamela (Fig. 5), there are higher *Artemisia* percentages than those observed in the western sector during this same period, so that Poaceae and *Artemisia* co-dominate. In the sequence from Pozo do Carballal, the end of this phase is dated to 10 360±210 B.P.

The Younger Dryas has also been recorded in other north-west Iberian pollen diagrams between 11 000 and 10 000 B.P. (van Mourik 1986; Ramil-Rego 1992, 1993; Ramil-Rego et al. 1993; Maldonado 1994; van der Knaap 1995; Allen et al. 1996). At that time, polar waters of the north Atlantic extended to north-west Iberia, and resulted in a substantial reduction in precipitation and temperature (Duplessy et al. 1991; Frenzel et al. 1992).

In the mountainous areas of south-west Europe, different variants of these herbaceous formations have been recorded, i.e. different types of steppe vegetation were present depending on the degree of humidity (de Beaulieu et al. 1994). Thus, in the Atlantic domain [cf. northern mountain ranges of Galicia (Ramil-Rego and Aira 1993)], there is an overall dominance of Poaceae with an almost complete absence of *Artemisia*. In other more eastern, but also oceanic mountainous areas, e.g. the western and central Pyrenees, lower percentages of *Artemisia* are observed, though Poaceae still dominate (Reille and Andrieu 1995). *Artemisia* representation increases in the interior mountains of the Iberian peninsula [cf. Iberian mountain range (Peñalba 1989; Gómez-Lobo 1993); Nevada mountain range (Pons and Reille 1988)]. Finally, *Artemisia* became the dominant element during the Younger Dryas in environments with strong seasonal contrasts, e.g. the eastern Pyrenees (Reille 1990, 1991). Applying the same reasoning to the results obtained in the western end of the Cantabrian mountain range, the orographic disposition of the Ancares massif must have resulted in more continental conditions in its eastern sector, as is also the case today.

4. The Early Holocene (RPAZs ANC-3 and ANC-4a)

After the cold Younger Dryas, the beginning of the Holocene was characterized by the expansion of tree-dominated vegetation as a result of the climatic improvement that affected the entire south-west of the continent after 10 000 B.P. (Duplessy et al. 1991; Frenzel et al. 1992). The Pozo do Carballal profile (Fig. 3) shows, at the beginning of the Holocene, a single expansion phase (cf. *Quercus robur*-type) which began at 10 370±210 B.P. This expansion reflects a rapid colonization by oak forests, but pollen of other taxa such as *Frangula, Sambu-*

Pozo do Carballal (Pedrafita do Cebreiro, Lugo) Altitude, 1330 m

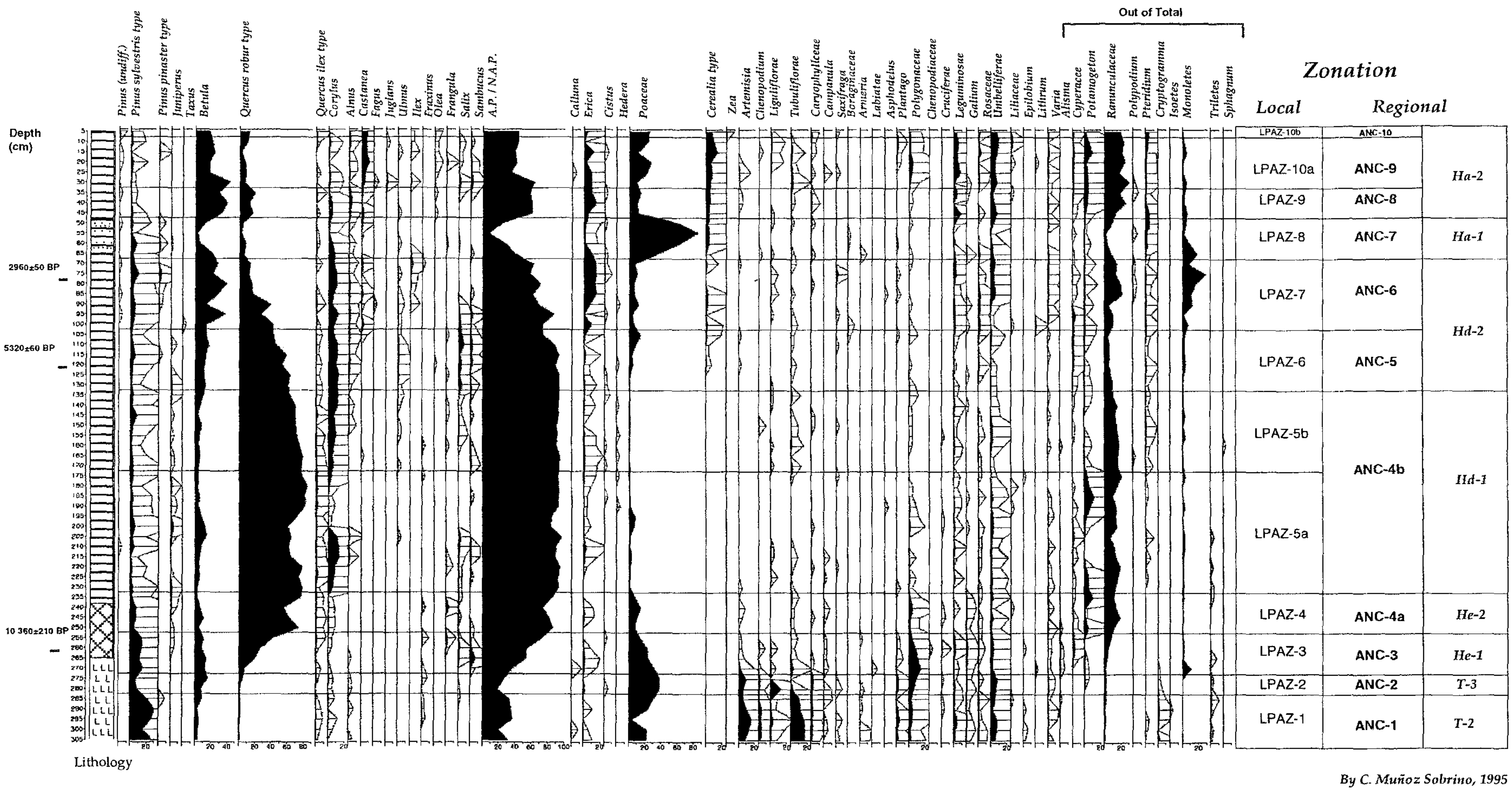

Fig. 3. Percentage pollen diagram, Pozo do Carballal

Suárbol (Candín, León) Altitude, 1080 m

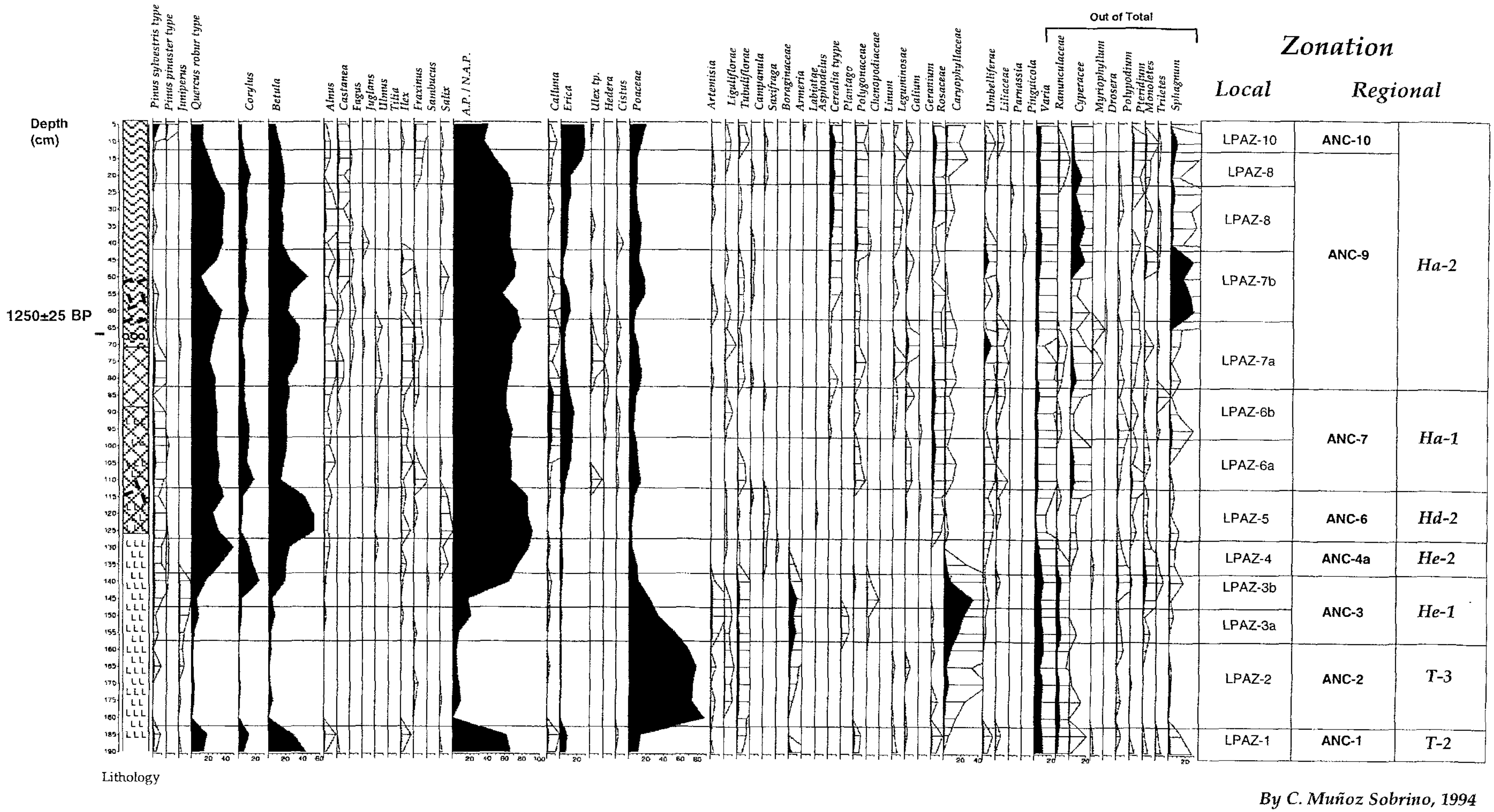

Fig.4. Percentage pollen diagram, Suárbol

Brañas de Lamela (Villafranca del Bierzo, León) Altitude, 1285 m

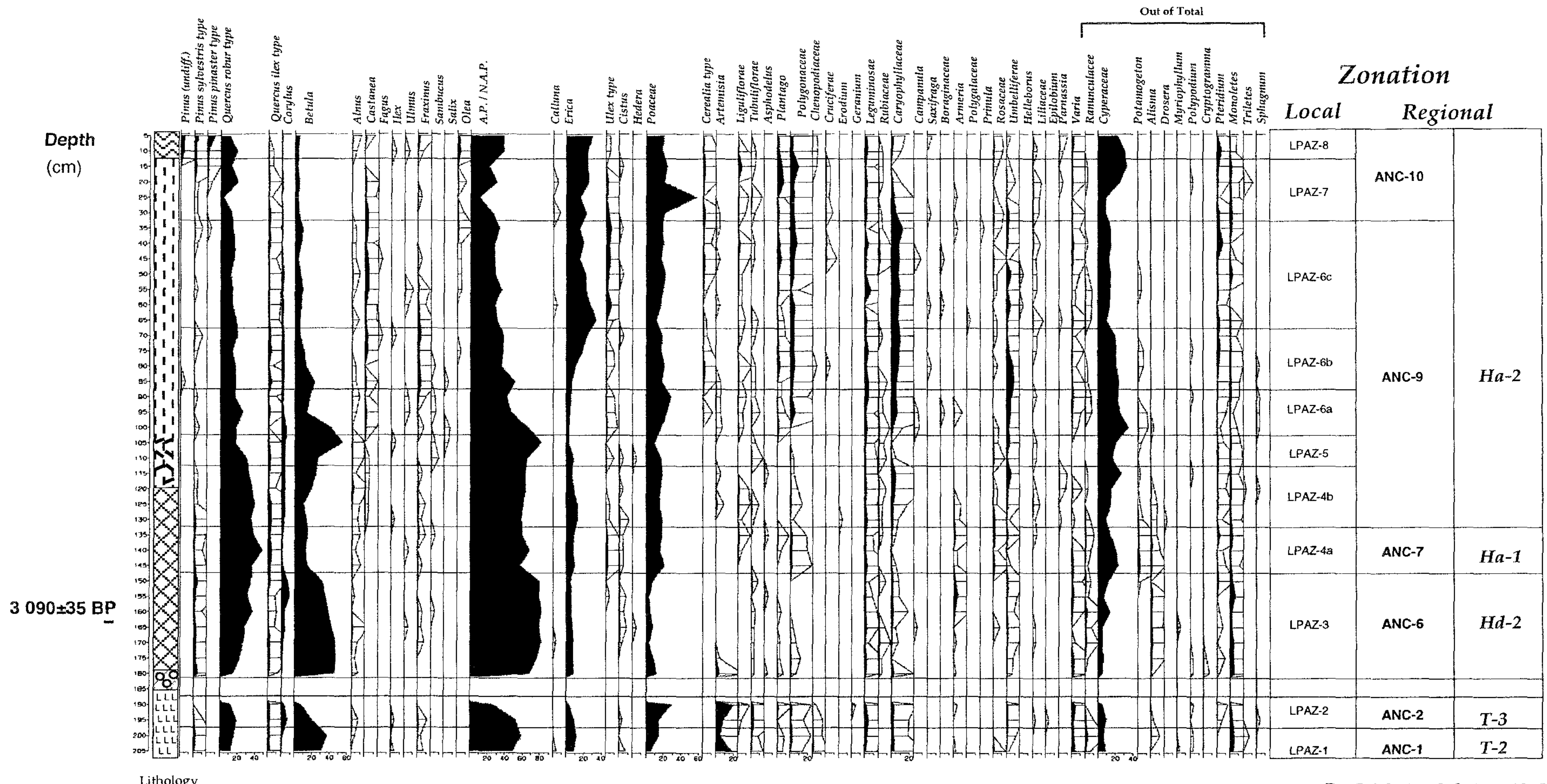

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Fig.5. Percentage pollen diagram, Brañas de Lamela

A *Golada (Pedrafita do Cebreiro, Lugo)* Altitude, 1200 m

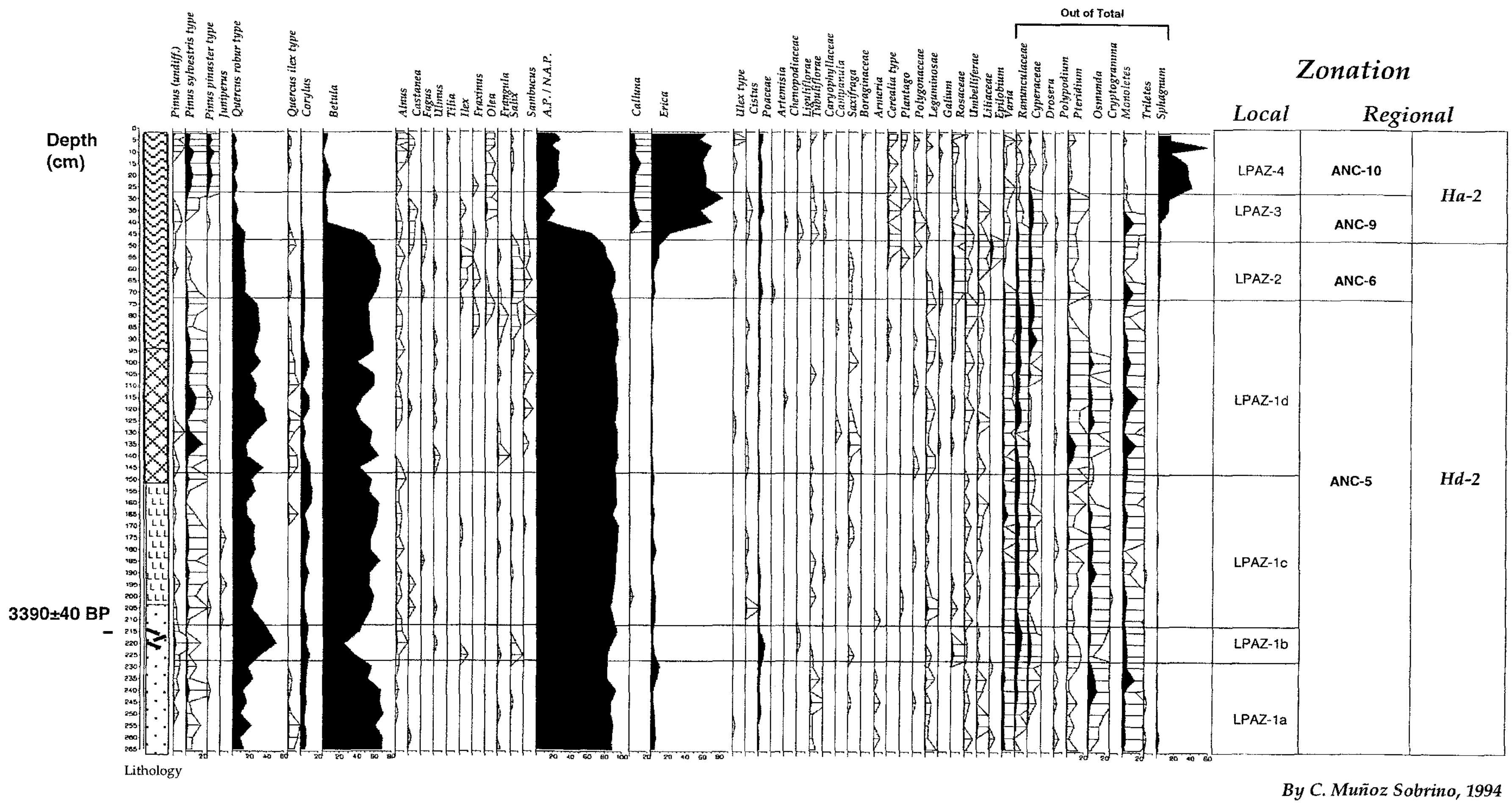

Fig. 6. Percentage pollen diagram, A Golada

Porto Ancares (Candín, León) Altitude, 1530 m

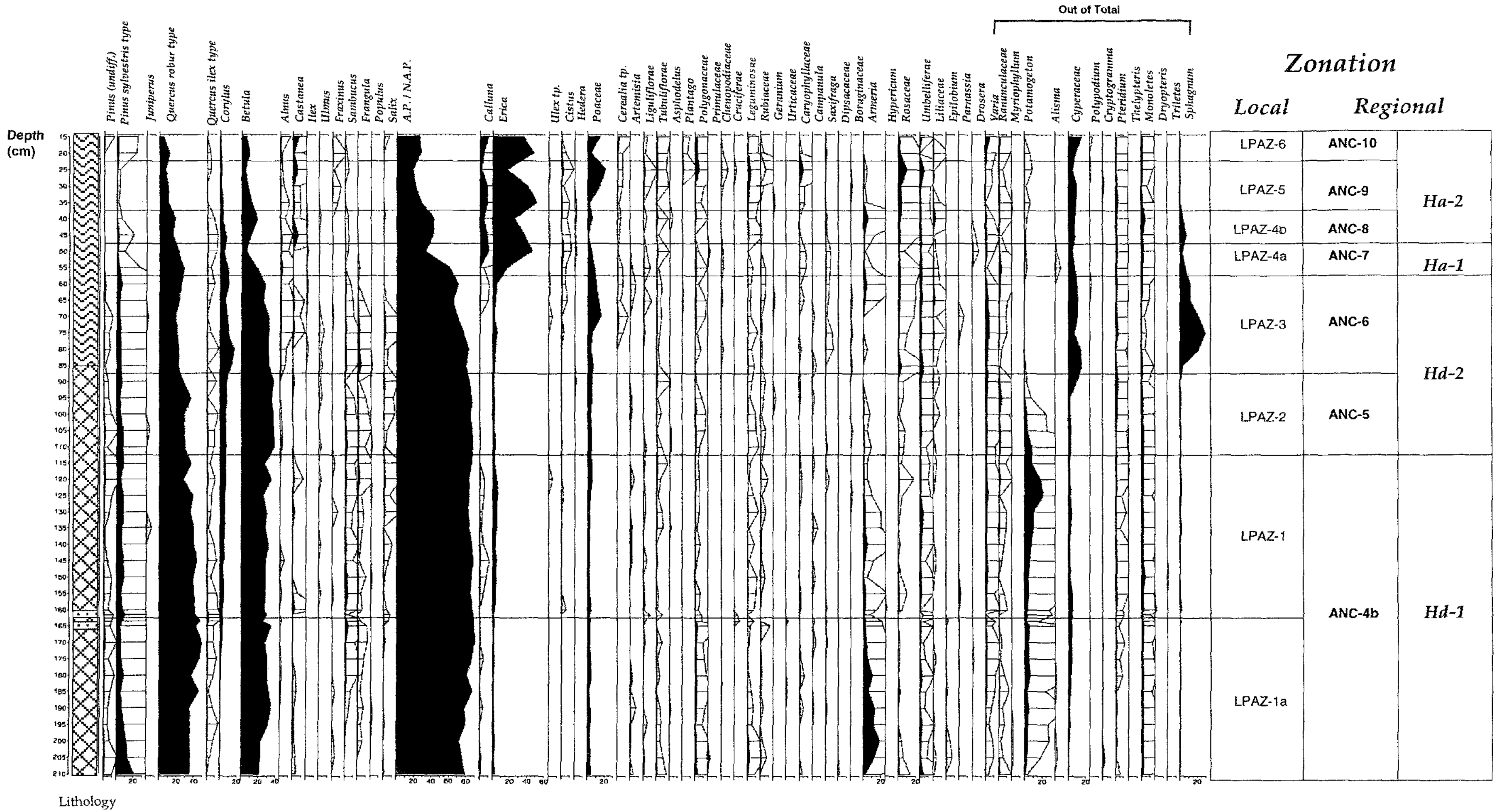

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Fig.7. Percentage pollen diagram, Porto Ancares

A Cespedosa-I (Navia de Suarna, Lugo) Altitude, 1415 m

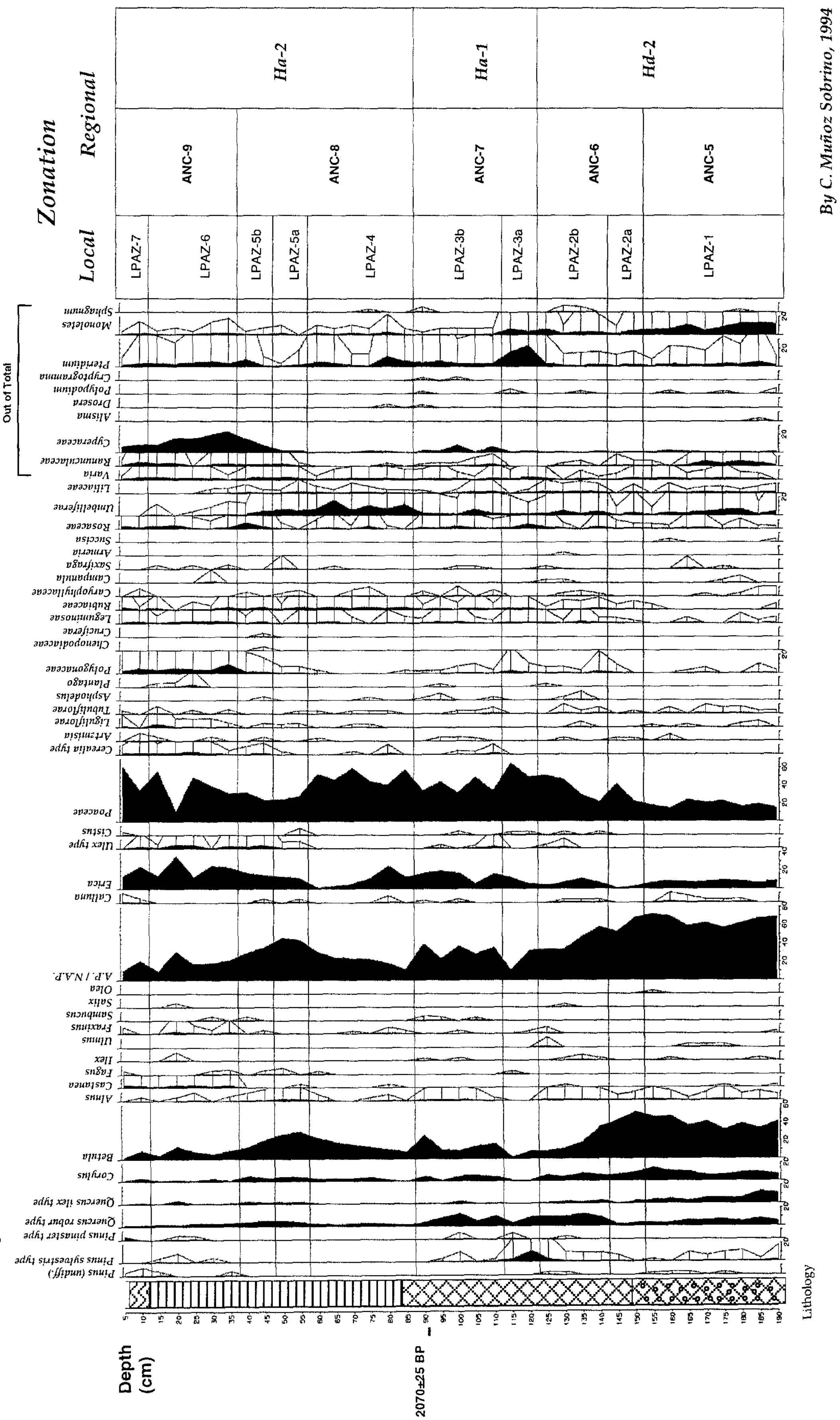

Fig. 8. Percentage pollen diagram, A Cespedosa-I

A Cespedosa-II (Navia de Suarna, Lugo) Altitude, 1415 m

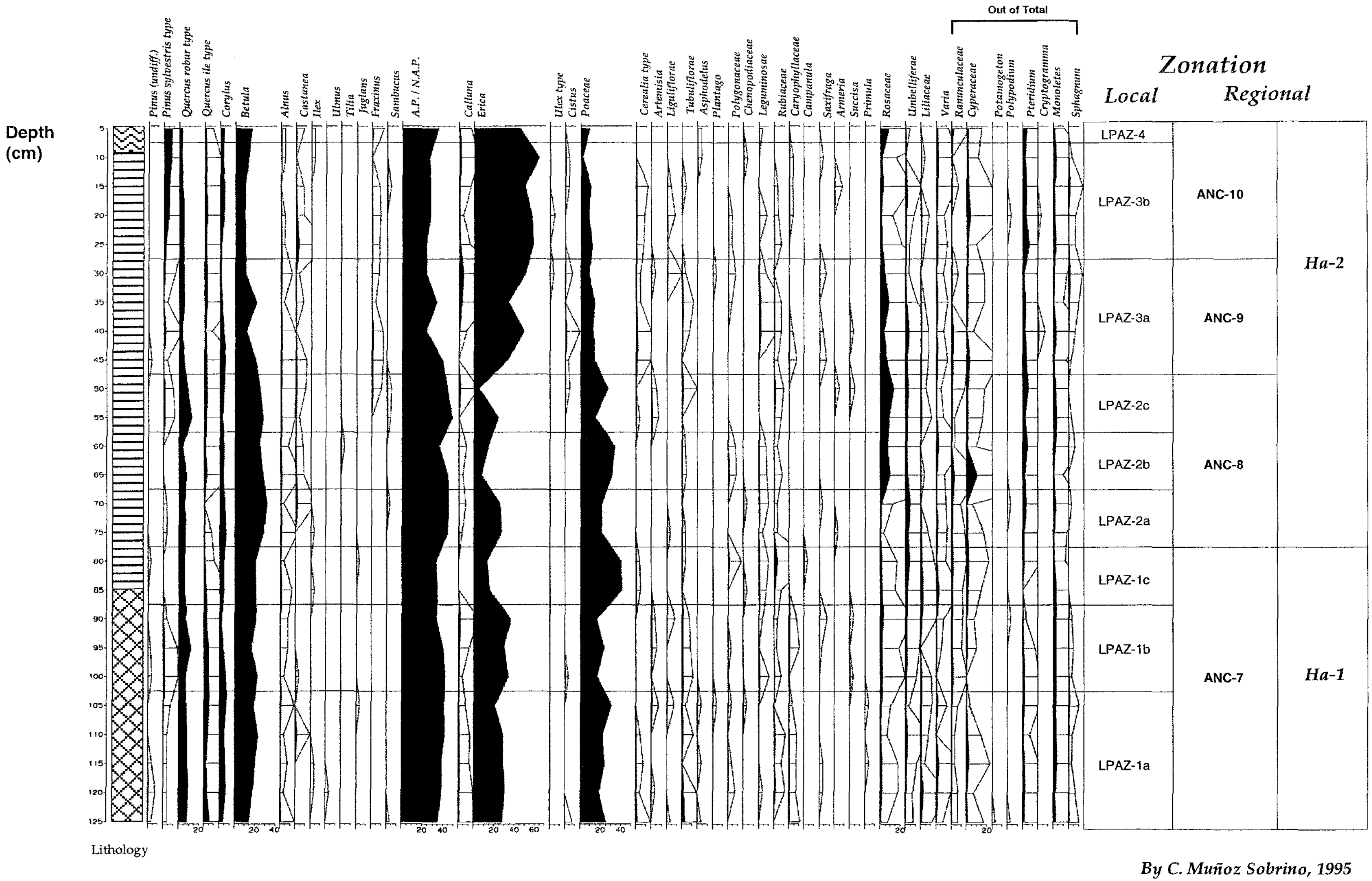

Fig. 9. Percentage pollen diagram, A Cespedosa-II

cus, Fraxinus, Ilex and *Salix*, and occasional *Corylus* are also recorded. The altitudinal pro-gress of this mesophilous forest must have reduced the area occupied by pine and birch forests, compared with the situation during the Late-glacial.

In the sequence from Suárbol (Fig. 4), on the other hand, there is a succession very similar to that recorded at Lago de Ajo (Allen et al. 1996), which is characterized by consecutive expansions of *Betula* and *Quercus robur*-type, followed by a rise in *Corylus*. Such a sequence is very similar to that observed in other oceanic environments in south-west Europe (Reille et al. 1985; de Beaulieu and Reille 1992; Reille and Andrieu 1991, 1995; Ramil-Rego and Aira 1993) and differs from the one recorded in the southern mountains of north-west Iberian [(cf. Arroyo de las Lamas (Maldonado 1994); Lagoa de Marinho (Ramil-Rego et al. 1993)], where the presence of *Betula* at the beginning of the Holocene, and of *Corylus* throughout the entire post-glacial, is much less important. It is also not comparable to the sequences from more continental environments, e.g. the Iberian mountain range (Peñalba 1989 1994) and Pena Trevinca-Sanabria (Allen et al. 1996), in which there is an important representation of *Pinus* and a scarce presence of *Corylus* throughout the entire Holocene.

The differing levels of *Corylus* representation in the northern and southern mountainous regions of the north-west Iberian peninsula is probably the result of differences in oceanicity/continentality in these regions. These differences were maintained throughout the Holocene and can still be recognised today in studies of both pollen representation (Aira and Barthelemy 1990) and floristics (Izco 1987).

5. The Mid-Holocene (RPAZs ANC-4b, ANC-5, ANC-6)

This period, which spans the interval 8500-3500 B.P., corresponds to the phase of greatest tree cover within the study area (AP close to 90%). From the point of view of pollen representation, it may be divided into three stages as follows:

1. RPAZ ANC-4b is characterized by the spread of different deciduous taxa, e.g. *Ulmus* and *Castanea*, in the dominant oak forests. The available data suggest that the presence of these taxa in the north-west Iberian peninsula dates from before the beginning of the Holocene (Mary et al. 1977; Sánchez Goñi 1988; Ramil-Rego 1993b). They generally tended to spread during the hottest and most humid periods, at least in the southernmost mountains of this area. Thus, *Ulmus* is recorded throughout the Late-glacial Interstadial in the vicinity of Lago de Ajo, reappearing later, after the Holocene tree expansion (Watts 1986; Allen et al. 1996). Parallel to this, *Ulmus* pollen is recorded at ca. 7500 B.P. in the Lagoa de Marinho profile (Ramil-Rego et al. 1993) and about the same time in the sequence from Arroyo de las Lamas (Maldonado 1994). As regards *Castanea,* its dynamics in these mountains are, broadly speaking, similar to those of *Ulmus*, although its presence is more irregular. It is recorded during the Late-glacial Interstadial in the diagrams of Suárbol (Fig.4) and Lagoa de Marinho (Ramil-Rego et al. 1993). Later on, it disappears during the Younger Dryas and it reappears in the mid-Holocene both at Suárbol and Lagoa de Marinho, and in Arroyo de las Lamas (Maldonado 1994).
2. In RPAZ ANC-5, beginning at 5230±60 B.P., there is an expansion of *Betula,* culminating in RPAZ ANC-6 with the maximum values of this taxon and a decrease in *Quercus* percentages. On the other hand, total AP representation remains steady, especially compared with the early part of the Holocene. The *Betula* (LPAZ-2) maximum was dated at A Cespedosa-I to before 2070±25 B.P., which would seem to indicate that the greatest expansion of birch forests was achieved in the Ancares mountain range before that date. In the sequence from Arroyo de las Lamas, there is a similar expansion of *Betula* dated to between 5620±100 B.P. and 2550±50 B.P., when it reached maximum values (Maldonado 1994).

The generally accepted global conditions for this latitude during the Mid-Holocene suggest greater humidity and higher temperatures that those at the beginning of the Holocene (Baroni and Orombelli 1996). Under these conditions, the expansion of *Betula* did not takes place in competition with the oak forests that had developed during the first half of the post-glacial. It should rather be attributed to an increase in the density of montanous birch forests and an altitudinal shift upwards as a result of favourable climatic conditions, at the expense of thickets (cf. Ericaceae and *Juniperus*) located above the forest limit.

In this pollen zone there are several records of cereal-type pollen (Pozo do Carballal, LPAZ-6), which may represent the first evidence of human activities in these territories. The beginning of these records date to 5320±60 B.P.

(c) The maximum pollen values of *Betula* are reached in RPAZ ANC-6 at the same time as total AP decreases. Similar reductions in AP are frequent in other pollen diagrams from the north-west Iberian peninsula from 3500 B.P. onwards (Van Mourik 1986; Peñalba 1989, 1993; Gómez-Lobo 1993; Maldonado 1994; Ramil-Rego et al. 1993) and, as in this case, are almost always associated with the beginning of a continuous cereal-type curve. This suggests that the decline in AP should be attributed mainly to anthropogenic perturbations, even though some decline in climatic conditions occurred during the last third of the Holocene (Baroni and Orombelli 1996).

It is probable that in the Ancares mountain range and nearby mountainous areas, the degradation of the forests started in the valleys at lower altitudes, i.e. the most favourable bio-climatic areas for the development of oak forests. Maximum *Betula* representation may reflect the good state of the montanous forests (formed mainly by birch forests) during this period.

In RPAZ ANC-6, coinciding with the decrease in AP, new deciduous elements also appear in the pollen record, e.g. *Fagus, Tilia,* and *Juglans*, which are normally recorded from the Mid-Holocene onwards in many pollen sequences from south-west Europe, e.g. Reille et al. 1985; de Beaulieu et al. 1988; de Beaulieu and Reille

1992; Reille 1991; Reille and Andrieu 1991, 1995; Montserrat 1992; Peñalba 1989, 1993; Gómez-Lobo 1993; Ramil-Rego 1992; Maldonado 1994. It has been suggested that the spread of these taxa towards the west of the Iberian peninsula took place in the Mid-Holocene, by way of the Pyrenees and the Cantabrian mountain range. It coincides with a more favourable humidity and temperature conditions (Peñalba 1994) so that these trees became established within the pre-existing forests.

However, the chronology that is presently available in the north Iberian peninsula for the appearance of the majority of these elements is quite similar to that obtained in other regions of south-west Europe (Table 5), and is almost synchronous at both ends of the Cantabrian mountain range. It therefore seems probable that sheltered areas existed in the surroundings of the Cantabrian mountain range characterized by suitable environmental conditions for this mesophilous flora during the coldest and driest phases of the Late Quaternary. It is envisaged that elements such as *Fagus, Tilia, Ulmus, Castanea, Acer, Juglans,* and *Carpinus* were confined to such areas and subsequently spread as climate improved.

6. The Late Holocene (RPAZ ANC-7, ANC-8, ANC-9 and ANC-10)

These pollen zones include the spectra corresponding to the last third of the Holocene. They are generally characterized by a decrease in AP, which eventually fall to less than 30%. However, the dynamics and magnitude of the deforestation process do not coincide exactly in all cases. On the contrary, the chronology and pollen characterization of the tree minima vary from site to site, conditioned by factors such as (1) varying levels of anthropogenic activity depending on altitude, (2) the over-representation of pollen of some elements that were located in the vicinity of the deposits, and (3) the possibility also of partial losses of the pollen record during phases of instability.

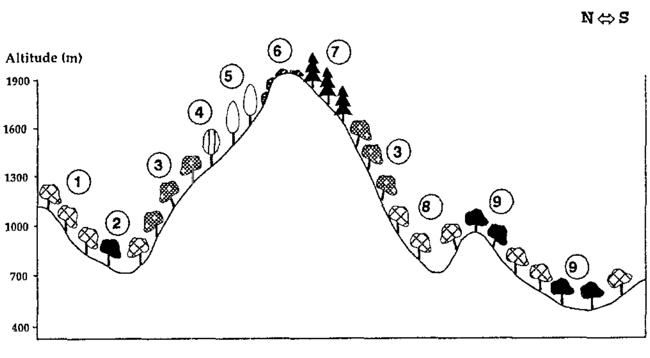

Fig. 10. Schematic representation of the vegetation at the time of maximum Holocene tree development in the Ancares mountain range. *1,* Oro-Cantabrian oak forests (*Quercus robur* and *Quercus pyrenaica*); *2,* holm oak forests (*Quercus rotundifolia*); *3,* sessile oak forests (*Quercus petraea*); *4,* beech forests (*Fagus sylvatica*); *5,* birch forests (*Betula alba*); *6,* thickets with juniper (*Juniperus communis* subsp. *nana*); *7,* pine forests (*Pinus*); *8,* Mediterranean forests of *Quercus pyrenaica*; *9,* Mediterranean holm oak forests (*Quercus rotundifolia*)

The severest deforestation is recorded in LPAZ-8, Pozo do Carballal, where AP is less than during the Younger Dryas (Fig. 3). LPAZ-3, profile A Golada shows a reduction in AP from 90% to <20% (Fig. 6). Profile A Cespedosa-I, from the north-western part of the study area, shows two deforestation events. The first (LPAZ-3) is dated to ca. 2070±25 B.P. (CSIC-1106; Fig. 8). Then, after a brief phase of *Betula* regeneration (LPAZ-4 and LPAZ-5), there is another decline in the AP values during which values comparable to those recorded in the previous deforestation phase are recorded. This 2nd decline coincides with the beginning of a continuous cereal-type curve (LPAZ-6 and LPAZ-7).

The sequence from Porto Ancares also shows a process of progressive deforestation with limited partial regeneration (Fig. 7). At Suárbol, and possibly also at Brañas de Lamela (Figs. 4, 5, respectively), minimum AP values are recorded at a later date (c. 1250±50 B.P.). The magnitude and dating of the increase in AP values in these two profiles are not comparable to those observed during the same period in the other profiles. This is probably due to the establishment of birch forests in the vicinity of both basins (these profiles have abundant macro-remains of *Betula alba* L. at the relevant levels).

Despite these differences, the pollen sequences from the Ancares mountain range share several characteristics during the Late Holocene, including (1) a local AP minimum at the beginning of the continuous curves for cereal-type and *Castanea*; (2) a general increase in taxa indicative of anthropogenic activity (cf. Behre 1981, 1988; Janssen 1994) such as Poaceae, Polygonaceae, Plantaginaceae, Rubiaceae, Liguliflorae, *Asphodelus,* and *Pteridium,* and (3) in profiles from the southern sector, the spread of *Olea* is recorded.

Taking the various features noted above into account, and correlating the various pollen analytical data from the Ancares mountain range, four regional phases may be delimited that reflect the most important aspects of the vegetation history of the region during the Late Holocene. These are as follows:

1. In RPAZ ANC-7 there is a marked decrease in AP values, following a trend that was initiated in the previous pollen zones. This phase corresponds to the interval between 3090±35 B.P. and 2070±25 B.P. Simultaneously, there is an expansion of scrub and herbaceous taxa, which may be interpreted as the result of an increase in the surface area occupied by thickets. In general, *Erica* is now the most abundant scrub element, accompanied, to a lesser degree, by *Calluna* and *Cistus.*
2. RPAZ ANC-8 shows a partial regeneration phase which indicates that the alterations that took place during the later Holocene in the Ancares mountain range forests was not a unidirectional process. Rather, at least in some of these mountains, periods of substantial deforestation alternated with phases of partial regeneration. These phases are dated between 2070±25 and 1250±50 B.P., and during this period *Betula* is the most abundant taxon, partially due to the fact that the decline of the oak forests must have favoured the expansion of heliophilous taxa, mainly *Betula,* at the lower-altitudes.

Table 5. Chronology (in ky B.P.) for the presence, spread and expansion of some mesothermophilous elements in the mountains of southern France and the north Iberian Peninsula

Geographical Area	>10 ky BP	10-8 ky BP	8-6 ky BP	6-4 ky BP	4-2kKy BP	2-0 ky BP	References
Hautes Alpes		●●●●●	●●●●●	●●●●●	●●●●●	●	
				◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	Reille, 1990
						■■■■■	
Massif Central			●●●●●	[●●●●●]	●	●	
			◆	[◆◆◆◆◆	◆◆◆◆◆]	◆◆◆◆◆	Reille et al., 1985
						■■■■■	
Eastern Pyrenees		●	●●●●●	●●●●●	●	●	
			◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	Reille, 1990; 1991
					■	■	
Central Pyrenees			●	●●●●●	●●●●●	●	
				◆◆◆◆◆	[◆◆◆◆◆	◆◆◆◆◆]	Reille, 1993
						■■■■■	
Western Pyrenees			●	●●●●●	●	●	
				◆◆◆◆◆	[◆◆◆◆◆	◆◆◆◆◆]	Reille and Andrieu, 1995
						■■■■■	
Eastern Cantabrian Mountain Range			●	●●●●●	●●●●●	●	
	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	[◆◆◆◆◆	◆◆◆◆◆]	Peñalba, 1989;
						■■■■■	Muñoz Sobrino et al., 1996
Western Cantabrian Mountain Range				●	●	●	Watts, 1986; Ramil-Rego, 1992
	◆			◆	◆	◆	Muñoz Sobrino et al.
					■	■■■■■	Ramil-Rego et al., 1996
Iberian Mountain Range						●	
				◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆	Peñalba, 1989
					■	■	Gómez-Lobo, 1993
Pena Trevinca-Sanabria							
						◆◆◆◆◆	Allen et al., 1996
						■■■■■	Janssen, 1996

	Presence	*Diffusion*	*Expansion*
Tilia	●	●●●●●	[●●●●●]
Fagus	◆	◆◆◆◆◆	[◆◆◆◆◆]
Juglans	■	■■■■■	---

3. RPAZ ANC-9 represents a second deforestation phase that dated to ca. 1250±50 B.P. This second AP minimum should be related to the period of minimum tree cover and maximum regional development of agriculture, which involved cultivation to higher altitudes especially during the Middle Ages. This is reflected in cereal-type curves in deposits at high altitude, e.g. A Cespedosa-I and Porto Ancares (Figs. 8, 7, respectively).
4. Finally, RPAZ ANC-10 is characterized by the appearance of pollen of new crops: *Zea mays* (Pozo do Carballal, LPAZ-10b) and an increase in *Pinus* values. This increase could be due to the plantations and expansion of population that began in the north-west Iberian peninsula before the 18th century (Ramil-Rego and Aira 1994). However, we cannot rule out the possibility that the increased representation *Pinus sylvestris*-type is due, at least partly, to natural regeneration of pine forests, especially since pine was present during the whole of the Holocene in the mountains of the north-west Iberian peninsula (Ramil-Rego et al. 1993; Maldonado 1994; Allen et al. 1996).

Conclusions

A comparison of the new data obtained in the mountains of the north-west Iberian peninsula with other studies undertaken in different areas of the north Iberian peninsula and in southern France, shows that the biogeographical complexity that presently characterizes the entire corridor between the Pyrenees and the Iberian peninsula's north-western coast goes back at least to the end of the last glacial period. Though the most important changes in vegetation cover during the last 13 000 years have been determined by large-scale climatic modifications, it seems unreasonable, therefore, to apply a single model of vegetation dynamics to such a large region.

During the Late-glacial Interstadial in the Ancares mountain range there was a co-existence of deciduous tree formations, formed by cryophilous (*Betula*) and mesophilous elements (cf. *Quercus robur*-type, *Corylus* and *Castanea*), along with thermophilous sclerophilous formations (*Quercus ilex*-type) and *Pinus* forests. However, the density and extension of the pine forests must have been considerably less than that recorded during the Interstadial in more southern mountains (Allen et al. 1996; Ramil-Rego et al. 1993) and, above all, in the eastern end of the Cantabrian mountain range (Muñoz Sobrino et al. 1996) and in the Iberian mountain range (Peñalba 1989).

Furthermore, in the pollen sequences from this mountainous sector there is a clear record of the Younger Dryas, a period characterized by the marked expansion of grasses and, to a lesser extent, by other cryophilous and/or xerophilous herbaceous taxa (*Artemisia*, Liguliflorae, Tubuliflorae and Chenopodiaceae). Tree expan-sion at the beginning of the Holocene is characterized in the Ancares mountain range by a strong predominance of the various deciduous *Quercus* taxa; other trees are less important (*Betula, Corylus* and *Pinus*). Tree dominance was maintained until the last third of the Holocene and throughout this period new tree elements such as *Ulmus, Castanea, Fagus, Tilia, Carpinus* and *Juglans*, were established in the oak forests as isolated occurrences or as small populations.

The patterns in vegetation cover in the mid-Holocene, based on pollen data and the results of studies on the present vegetation, enable us to establish the various altitudinal vegetation belts (Fig. 10). The subalpine belt at least partially consisted of grasses and thickets of Ericaceae and *Juniperus*. At lower altitudes, the first forest zone occurred in which *Betula* was the dominant taxon and with more sporadic occurrences of *Quercus, Pinus, Ilex* and *Taxus*. The mid- and low-altitudinal belts on the slopes were occupied by oak forests with *Corylus* (more abundant in the north-western sector), *Castanea, Frangula, Ulmus, Tilia, Fagus, Fraxinus, Sambucus* and *Ilex*, and the possible appearance of *Quercus ilex* in the form of isolated ocurrences or in small forests, mainly in the south-eastern parts of the massif. Along water-courses, corridor forests were present consisting of *Alnus, Salix* and *Fraxinus*, along with *Populus* at low-altitudes in the valleys of the eastern sector.

The anthropogenic perturbations that took place in these mountains after 3500 B.P. gave rise to an increase in heliophilous vegetation (*Betula*) and thickets (*Erica, Calluna* and *Cistus*). Unlike other parts of south-west Europe, where the perturbation of deciduous forests (*Quercus, Corylus, Betula* and *Tilia*) seems to have favoured the extension of beech forests during the later part of the Holocene (Reille et al. 1985; Peñalba 1989; Reille and Andrieu 1995), *Fagus* representation in the profiles from the western end of the Cantabrian mountain range reflect only isolated occurrences or small stands of beech. This distribution pattern can be related to the present-day plant formations in the eastern and south-eastern mountains of Galicia (Izco 1987; Rodríguez Guitián et al. 1996), which are presently the western limit of their distribution in Europe. To a certain extent, therefore, the *Fagus* expansion that has taken place in the Massif Central, the western Pyrenees and the eastern end of the Cantabrian mountain range during the final third of the Holocene, may be comparable to the dominance achieved by *Betula* in the mountains of the north-west Iberian peninsula during the Late Holocene.

The final regression of AP values is related to the agricultural development in this mountainous sector. Deforestation does not seem to have been a continuous process, since the pollen records reveal two different tree minima; the first at ca. 2070±25 B.P. and the second after 1250±50 B.P., and these were separated by a brief tree regeneration phase. The second tree minimum was probably the result of the extension and upward altitudinal progression of crops that took place during the Middle Ages. This period also marked the beginning of iron ore extraction in the eastern valleys of the Ancares mountain range (Gutiérrez et al. 1993), with the cutting down of forests near the deposits, to obtain the necessary wood and coal for foundries, being the main impact on the environment of the mining. Furthermore, the demand for wood increased during the following centuries to meet the demands of shipbuilding and railroad construction.

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