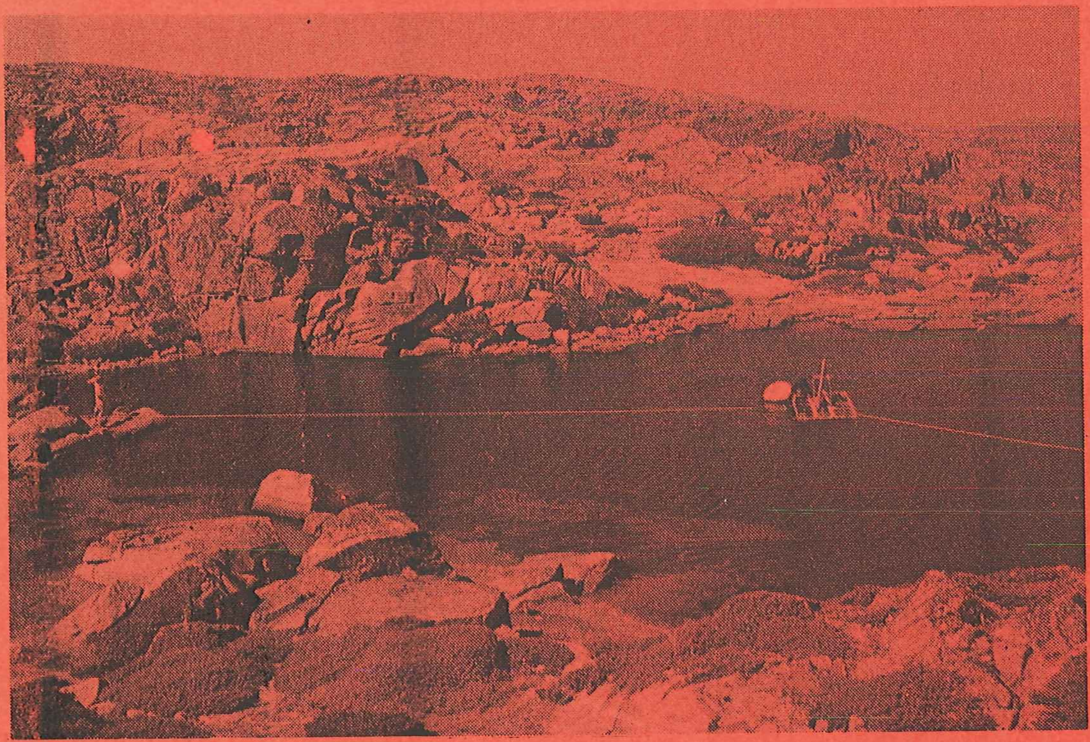
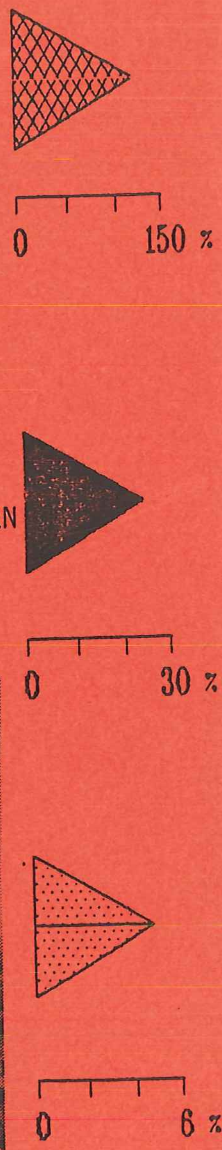
1991

UTRECHT ON THE ROCKS





XV. PEAT EXCURSION OF THE SYST.-GEOBOT. INSTITUTE, UNIVERSITY OF BERN

SECOND PART

SERRA DA ESTRELA (PORTUGAL)

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Manteigas
Alpiarça
Alcácer do Sal
Lisboa (Lisbon)
Porto
Coimbra
Évora
Beja
Faro
Setúbal
Santarém
Castelo Branco
Guarda
Viseu
Braga
Bragança
Badajoz
Salamanca
Sevilla
Cádiz
Córdoba
Valladolid
Huelva
Mérida
Gibraltar (To UK)
TRÁS OS MONTES
MINHO
ALTO DOURO
BEIRA
ALENTEJO
ALGARVE
EXTREMADURA
ANDALUCIA
Golfo de Cádiz
Costa del Sol

Polunin & Walters, 1985: A guide to the vegetation of Britain and Europe.

10 Mediterranean vegetation (Plates 30–42; Plates 104–131)

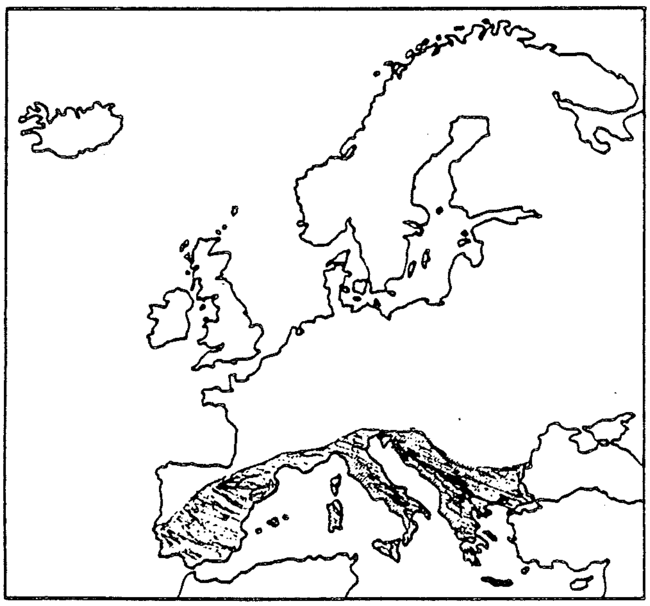
The vegetation of the Mediterranean region (Map 22) is quite distinct from that of any other region in Europe. It is dominated by evergreen trees, shrubs, and shrublets which can survive the long hot summers without rain. Most of the herbaceous plants die right down and remain inactive in the summer with dormant buds in the soil while the annuals complete their life cycle by the summer. Such a contrasting and unique type of climate has favoured types of vegetation that occur nowhere else in Europe. At the same time man's early colonization of the Mediterranean shores has resulted in his prolonged and intensive influence on the vegetation of the region. Consequently today little remains of the natural plant communities. Plant communities persisting to the present day are either scattered woodlands which survive in localities that have not been destroyed by man or his animals, or more commonly dense evergreen scrub known as *maquis* or, more widespread still, dwarf, scattered, mostly evergreen shrublets, the *garigue (phrygana)*. Many of the woody species have small thick leathery leaves which reduce transpiration during the dry summer; many are aromatic, releasing ethereal oils, thus possibly reducing water-loss and deterring grazing. Active growth and flowering takes place in the autumn and often throughout the winter, and reaches its peak in the spring.

The dominating trees in the Mediterranean zone are evergreen oaks and pines, with many evergreen shrubs such as juniper, heathers, cistus, spiny broom, strawberry trees, lentisc, and others, while the olive (Map 23) and carob are characteristic. However, due to the long and intensive occupation of the Mediterranean coasts by man, almost nothing remains of the true natural woodland communities, and shrub communities maintained by cutting, firing, grazing, and the resultant erosion of the soil have taken the place of the evergreen woods. In places the soil has become so eroded that the exposed bed-rock supports only a sparse steppe-like community of scattered herbaceous plants which is nevertheless composed of an interesting and rich assortment of species which flower in spring. Elsewhere olive trees have been widely planted, often on terraced hill slopes.

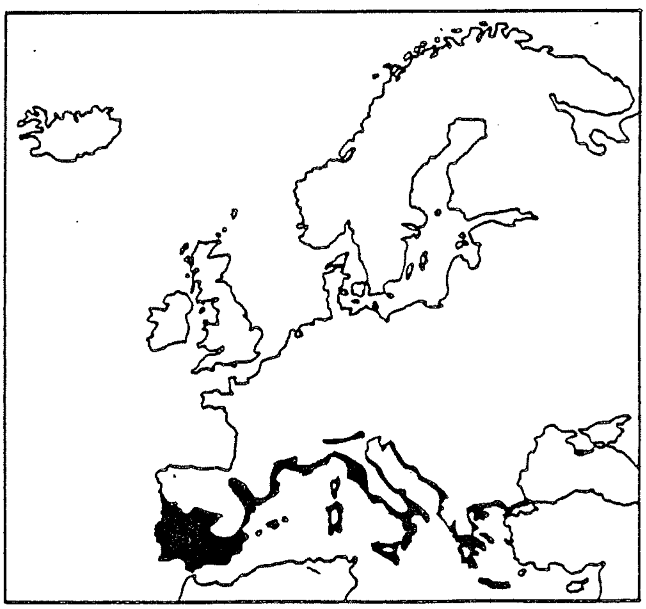
Inland in the hill region a sub-Mediterranean zone occurs which is less affected by the long drought and hot summers and has a higher rainfall. Here deciduous trees and shrubs largely replace the evergreens; these bush communities are known as *šibljak* in the Balkan region. Several species of deciduous oaks, with other trees such as hop-hornbeam, maples, manna ash, beech etc., are dominant, and coniferous woods, largely of black pine, occur. Other much more local deciduous woods in the east are dominated by sweet chestnut, horse chestnut, walnut, and plane. There are also some very local and degraded juniper woods in the hills in both the east and west.

The higher mountain regions bordering the Mediterranean have distinctive coniferous forests composed of several species of pine and fir, both in the Iberian and Balkan peninsulas. Hedgehog-heath communities of dwarf cushion-forming shrubs often occur above these forests.

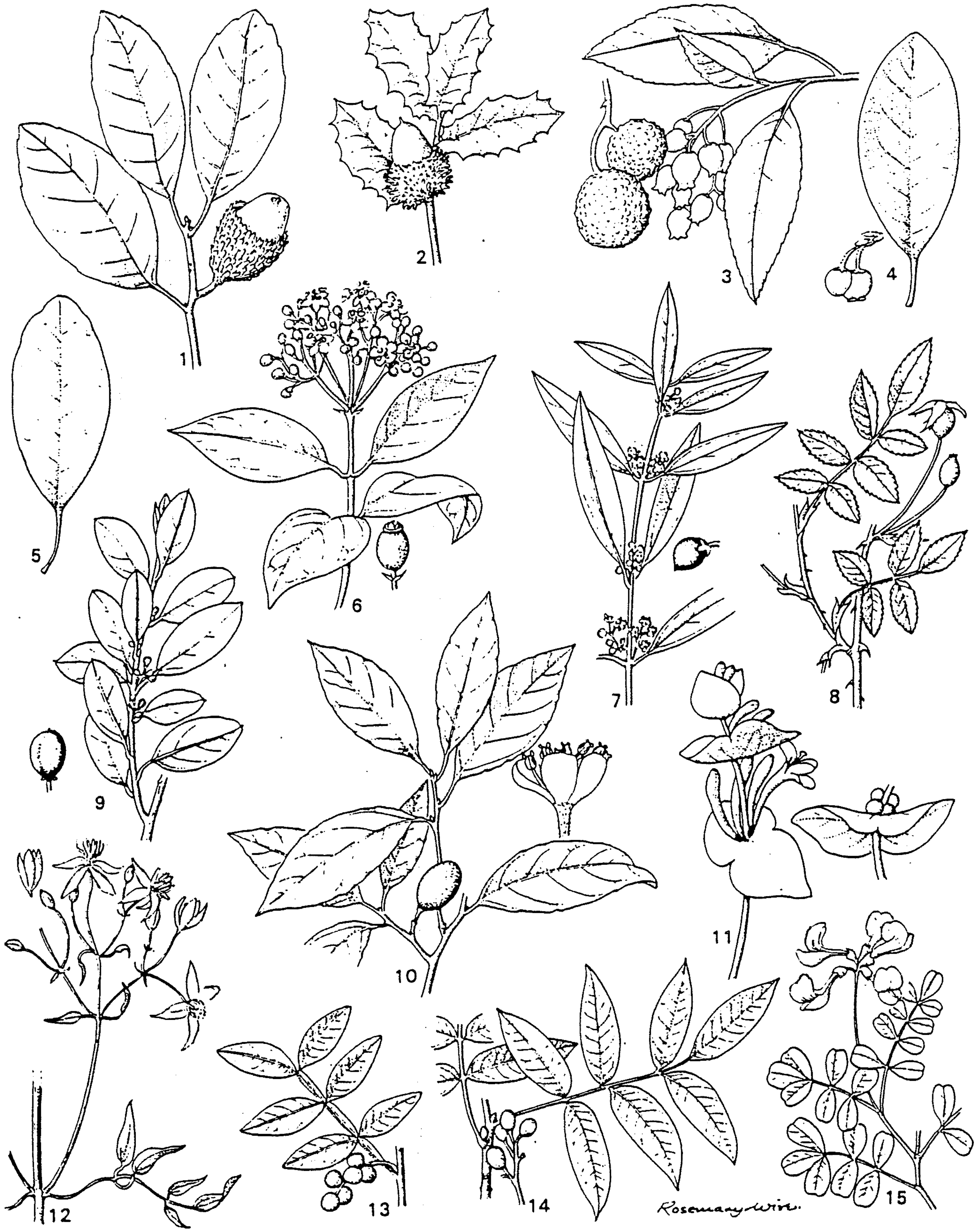
Grasslands in the Mediterranean are largely steppe-like, with feather-grasses, esparto grasses, etc. They are largely maintained as grasslands by the grazing of goats and sheep, or as a result of continued soil erosion due to the short but heavy local rainstorms. *Montane grasslands* are also largely man-made following forest and shrub clearance and they are maintained in this condition by the regular grazing of flocks, which are brought up from the lower hills and are found grazing over the highest mountains in the summer months.



Map 22. Mediterranean region. in Europe !

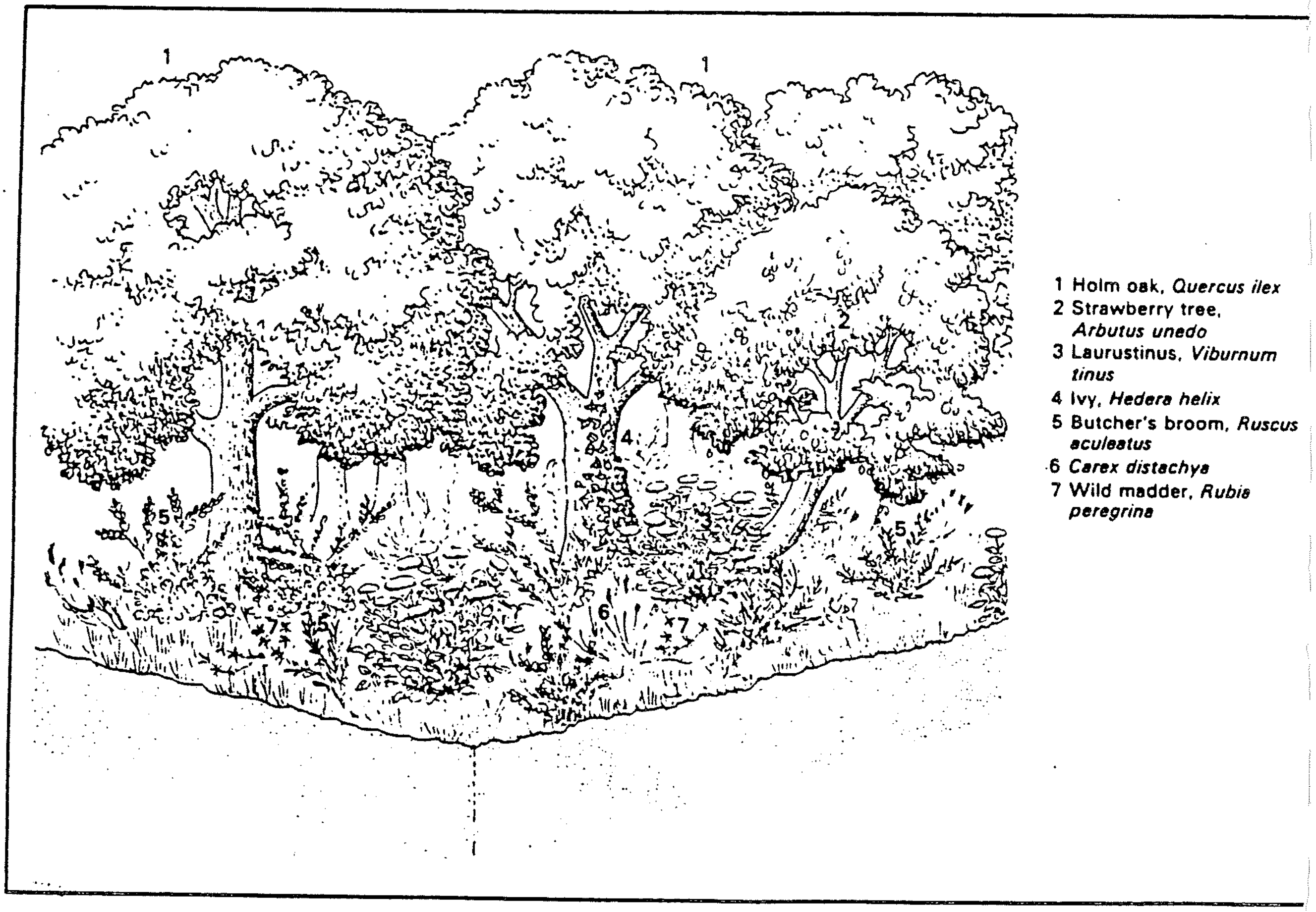


Map 23. The cultivated Olive *Olea europaea* var. *europaea* has a truly Mediterranean distribution.

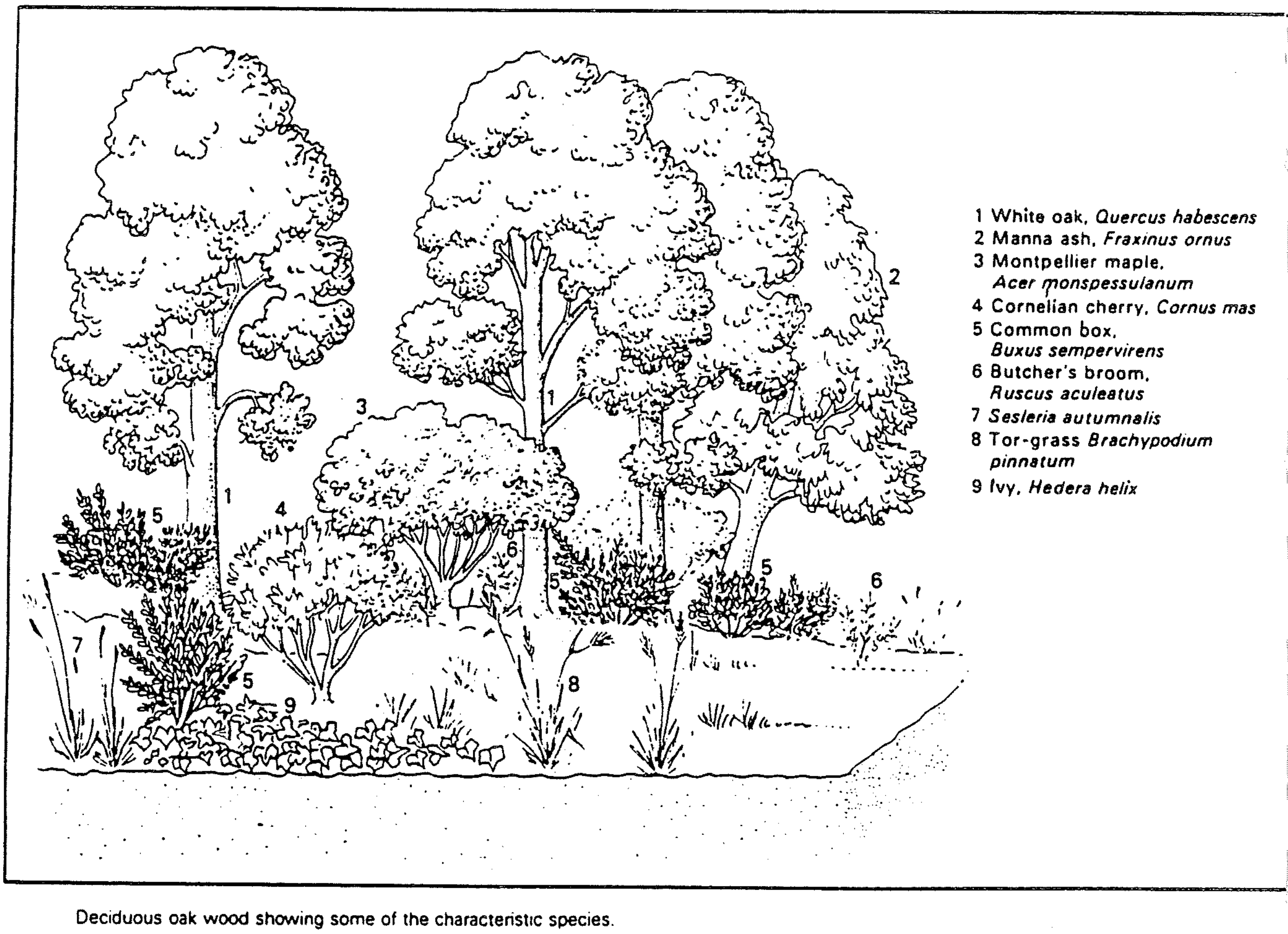


Mediterranean evergreen oak woods—trees and shrubs

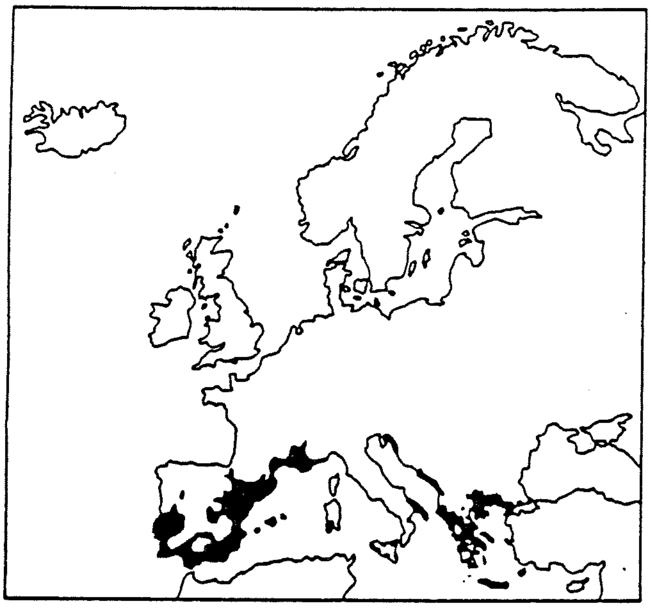
1. Cork oak, *Quercus suber*; **2**. Kermes oak, *Quercus coccifera*; **3**. Strawberry tree, *Arbutus unedo*; **4**. Eastern strawberry tree, *Arbutus andrachne* (leaf and flower); **5** Holm oak, *Quercus ilex* (leaf); **6**. Laurustinus, *Viburnum tinus* (inset×2); **7**. *Phillyrea angustifolia* (inset×2); **8**. *Rosa sempervirens*; **9**. Mediterranean buckthorn, *Rhamnus alaternus*; **10**. Laurel, *Laurus nobilis* (inset×3); **11**. Minorca honeysuckle, *Lonicera implexa*; **12**. Fragrant clematis, *Clematis flammula*; **13**. Mastic tree, *Pistacia lentiscus*; **14**. Turpentine tree, *Pistacia terebinthus*; **15**. Scorpion senna, *Coronilla emerus*.



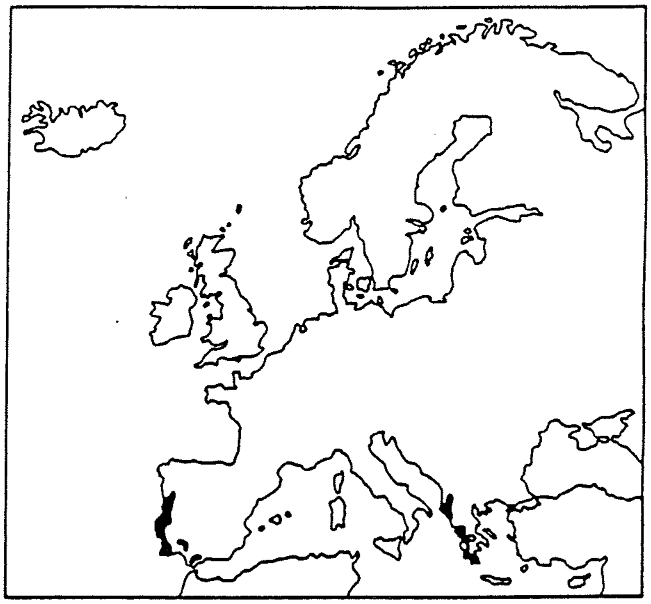
Evergreen oak wood Natural holm oak woods like this are rare today. When well grown they may be shady and have a dense shrub-layer of species familiar from the maquis. Species shown here: Holm oak *Quercus ilex*; Strawberry tree *Arbutus unedo*; Laurustinus *Viburnum tinus*; Ivy *Hedera helix*; Butcher's Broom *Ruscus aculeatus*; *Carex distachya*; Wild Madder *Rubia peregrina*.



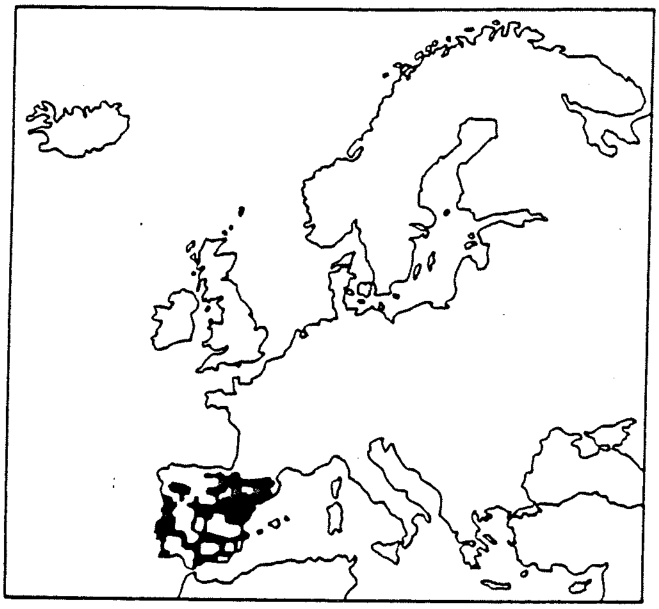
Deciduous oak wood showing some of the characteristic species.



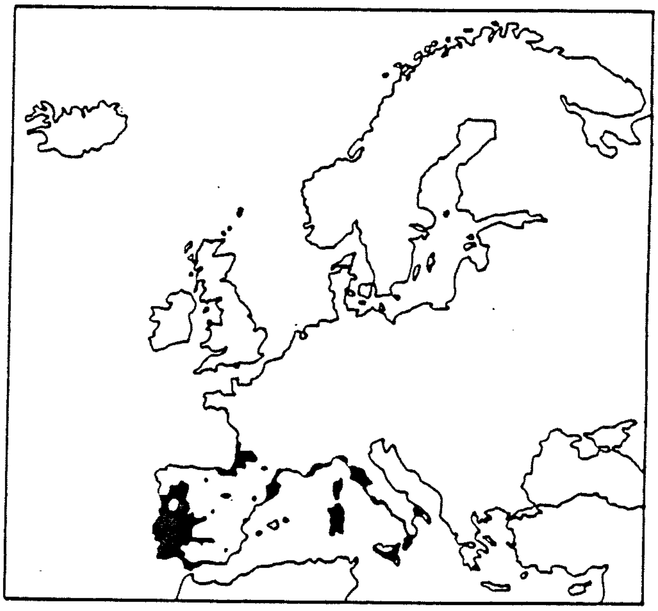
Kermes or holly oak *Quercus coccifera*.



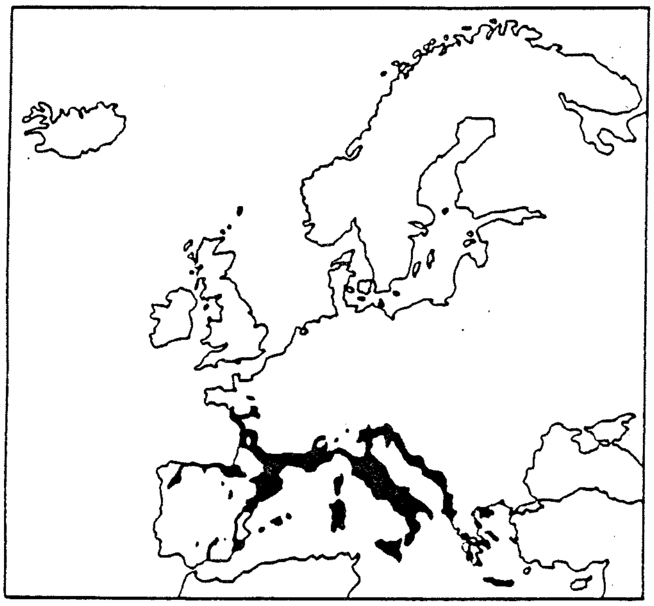
Q. *fruticosa* (west) Q. *macrolepis* (east)



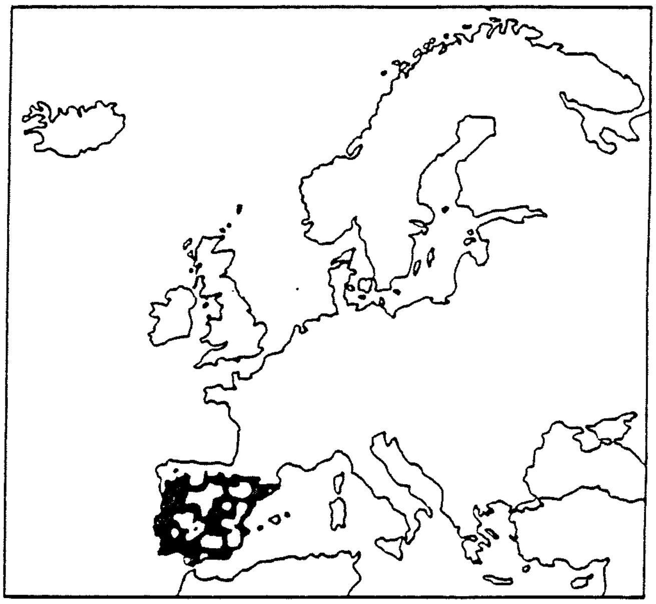
Lusitanian oak *Quercus faginea*.



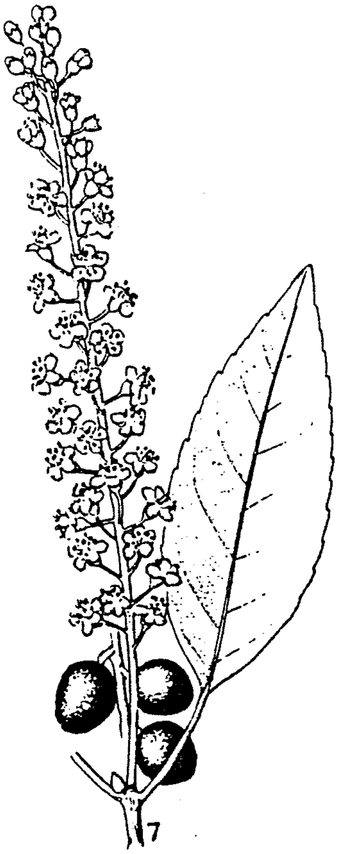
Cork oak *Quercus suber*.



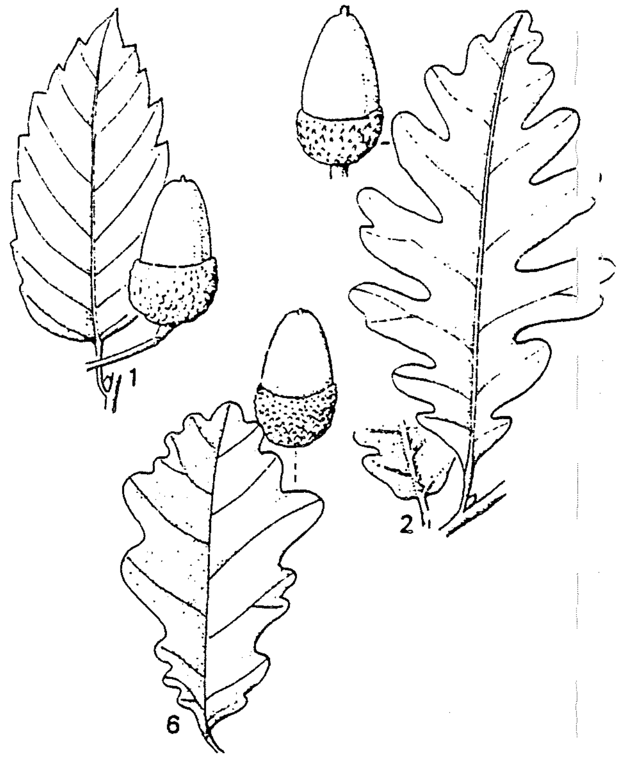
Holm oak *Quercus ilex*.



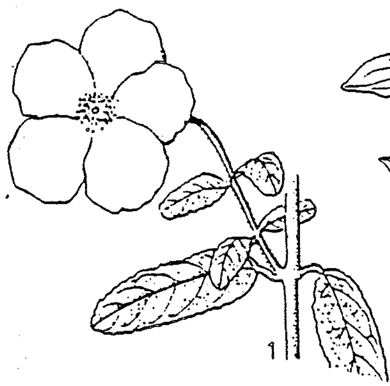
Quercus rotundifolia.

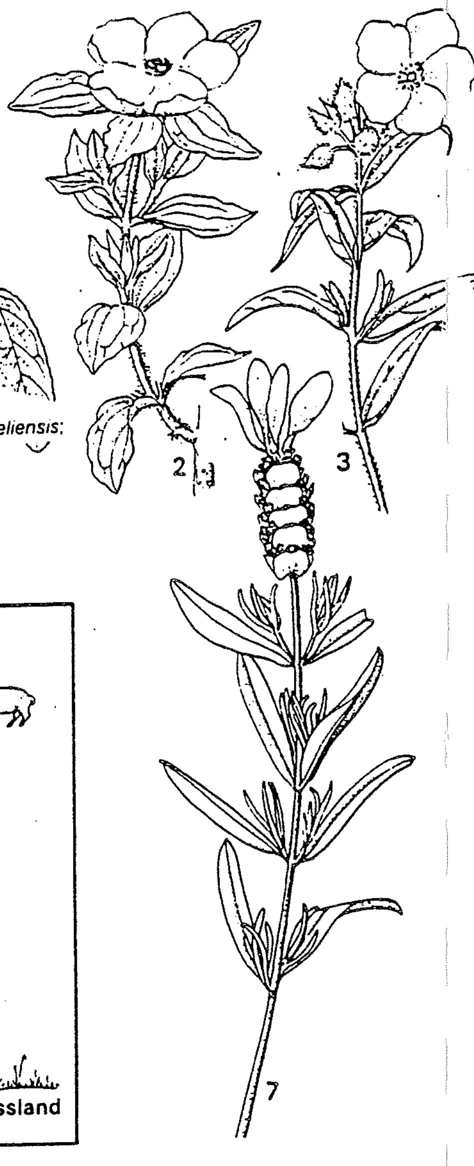


Portugal laurel, *Prunus lusitanica* (inset×1);



Mediterranean deciduous oak woods—trees
1. Portuguese oak, *Quercus faginea*; 2. Pyrenean oak, *Quercus pyrenaica*; *frainetto*; 5. Macedonian oak, *Quercus trojana*; 6. White oak, *Quercus pubescens* (leaf);





Mediterranean garigue—shrubs and dwarf shrubs
1. Sage-leaved cistus, *Cistus salvifolius*; 2. *Cistus crispus*; 3. Narrow-leaved cistus, *Cistus monspeliensis*; *Erica cinerea*; 6. Spiny spurge, *Euphorbia spinosa*; 7. French lavender, *Lavandula stoechas*;

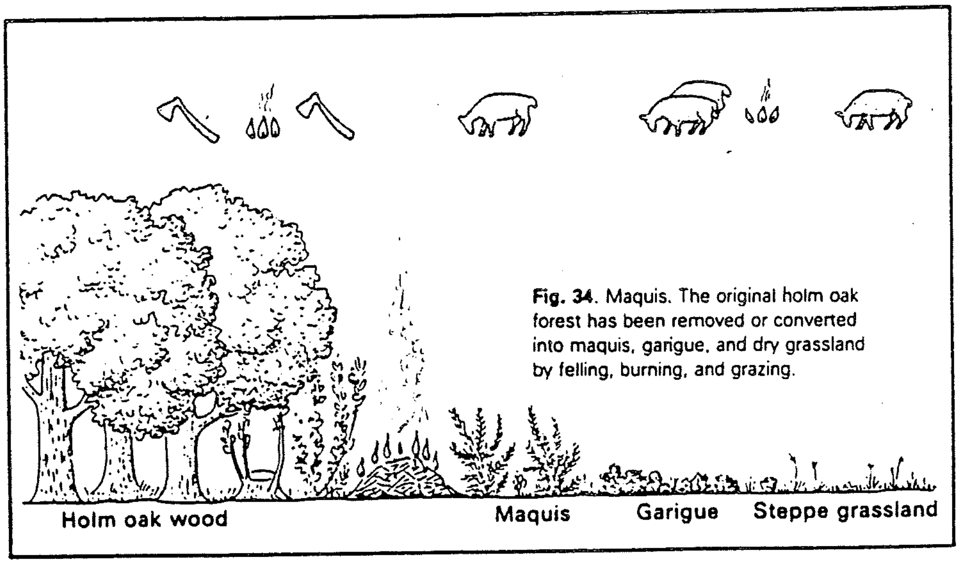
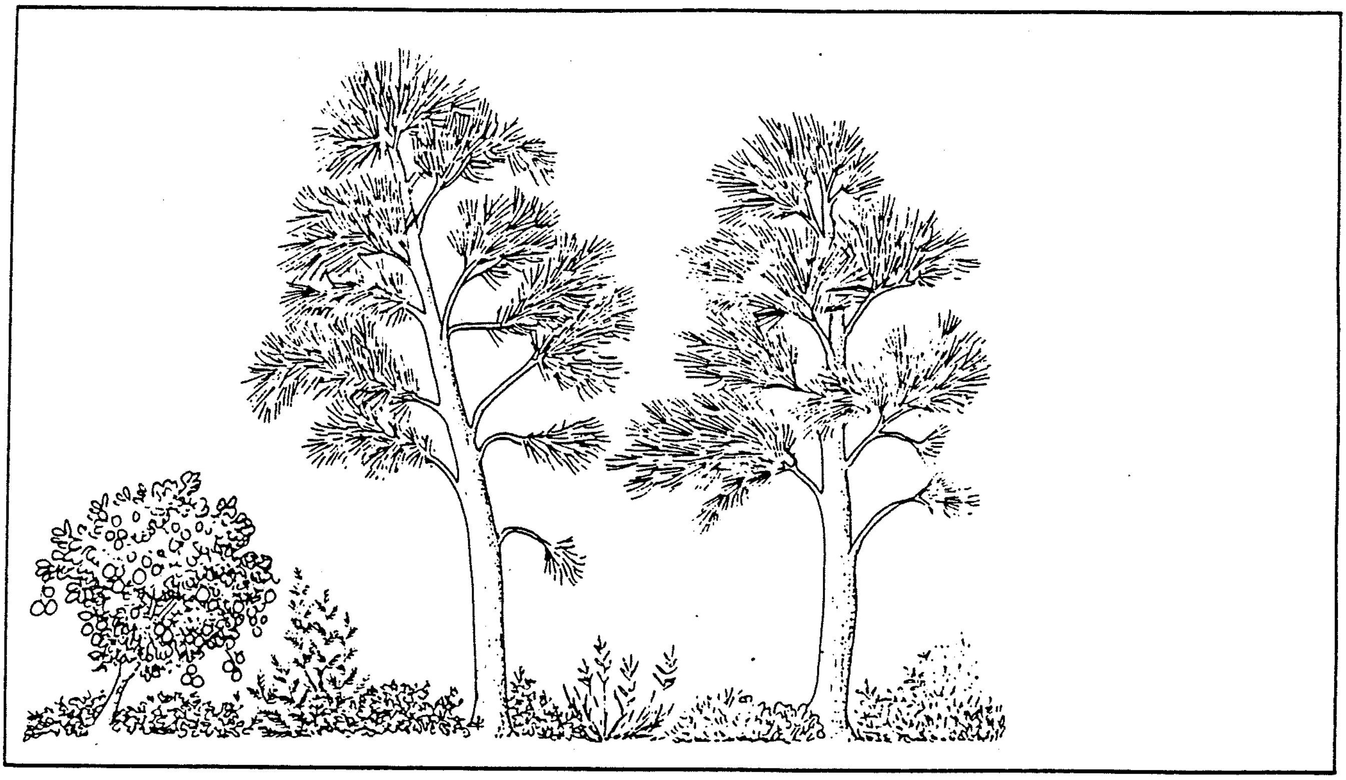
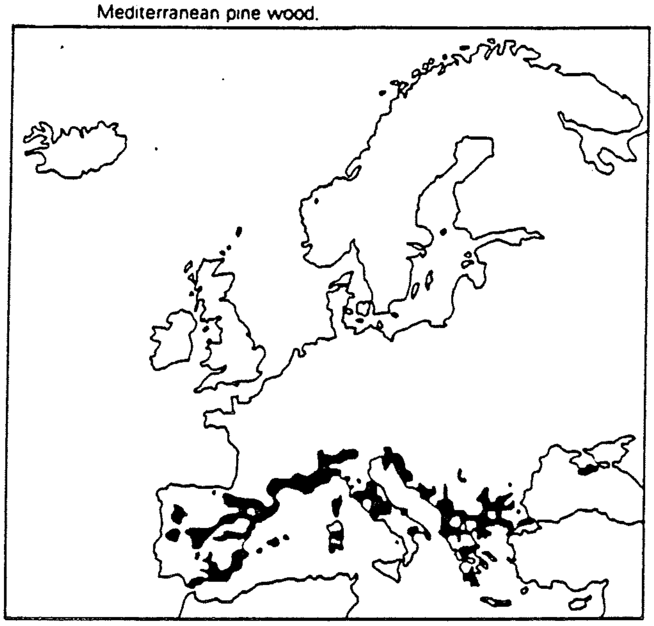


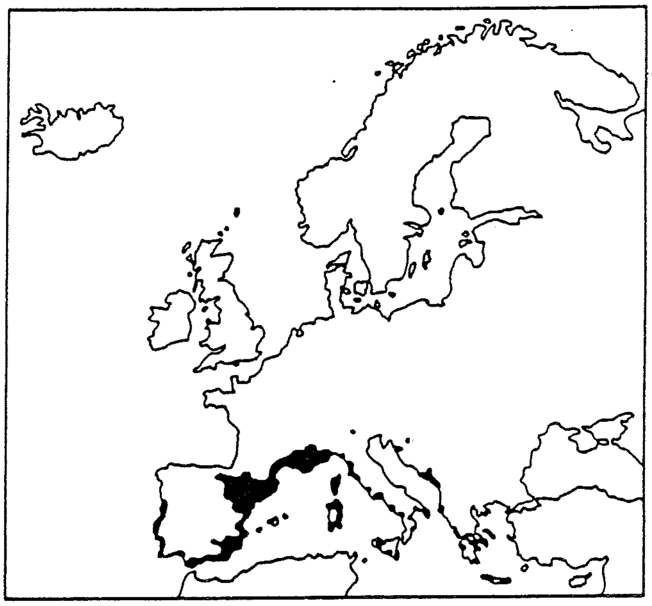
Fig. 34. Maquis. The original holm oak forest has been removed or converted into maquis, garigue, and dry grassland by felling, burning, and grazing.



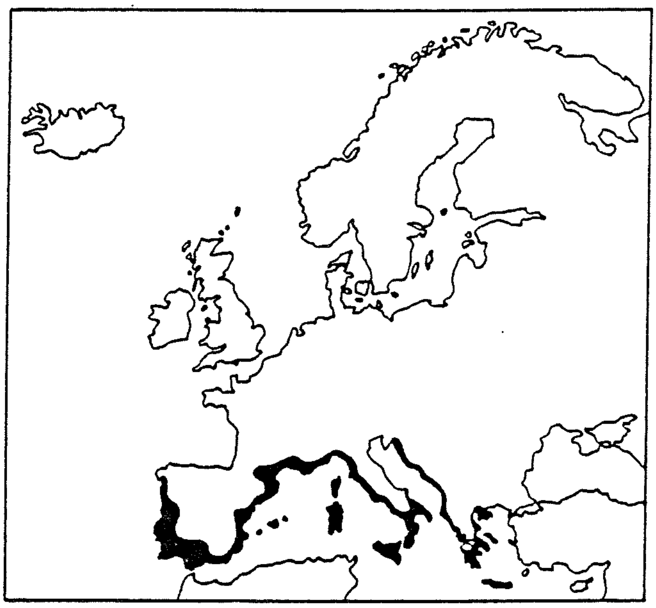
Mediterranean pine wood.



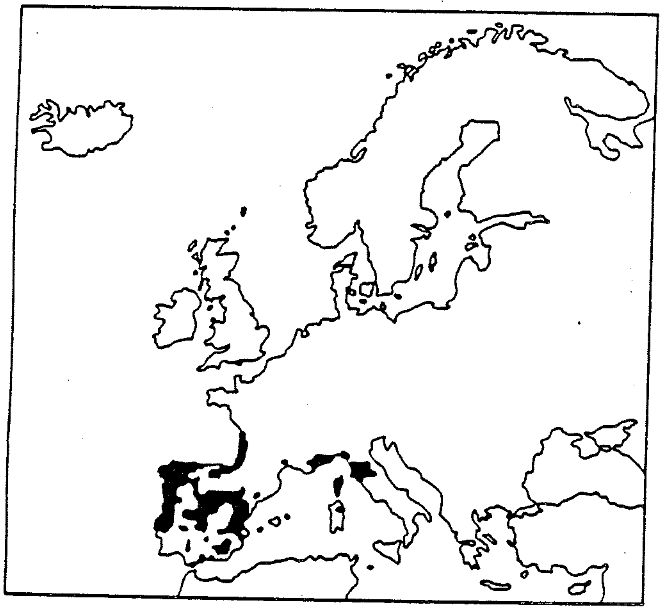
Prickly juniper *Juniperus oxycedrus*.



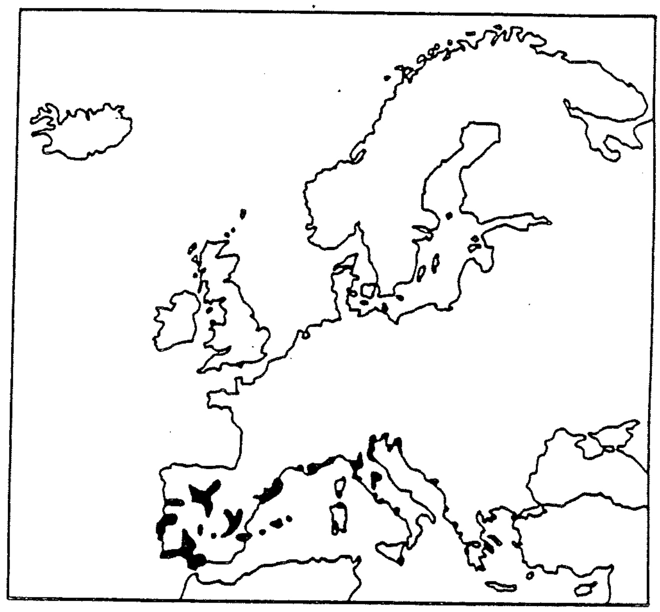
Phoenician juniper *Juniperus phoenicea*.



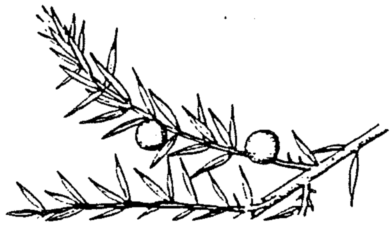
Narrow-leaved cistus *Cistus monspeliensis*.



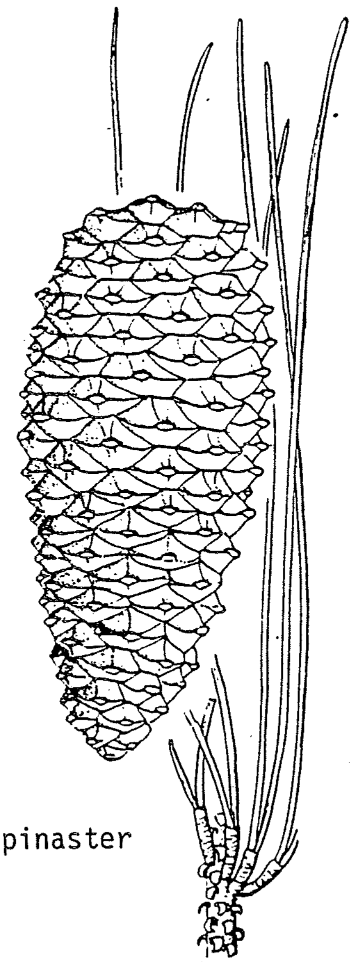
Maritime pine *Pinus pinaster.*



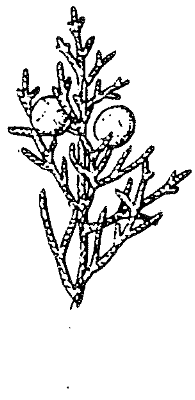
Stone pine *Pinus pinea.*

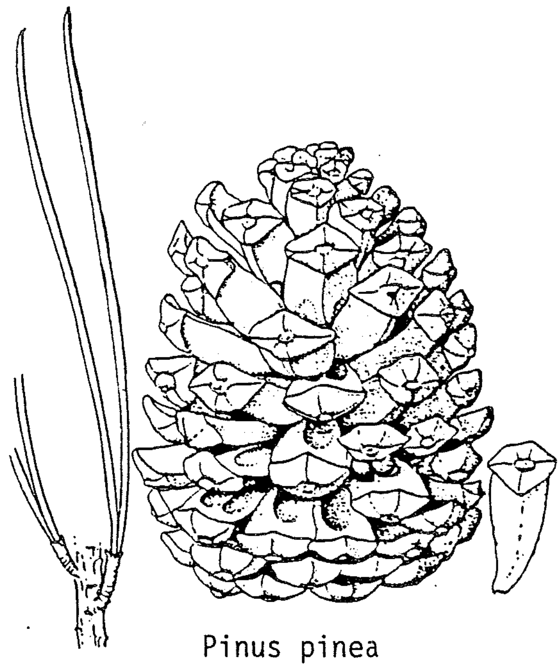


Prickly juniper, *Juniperus oxycedrus.*



Pinus pinaster





Pinus pinea

NOTES ON THE FAUNA OF PORTUGAL

Jacqueline van Leeuwen

Here follow a few notes on the fauna of Portugal. The notes are restricted to species we might encounter in this season in the regions visited, and to animal groups of my personal interest. For ease of many readers, English animal names will be followed in parentheses by scientific names and/or German names.

Birds

Birds of the dune area

The Iberian Peninsula has several bird species which are of special interest to those coming from temperate regions. The first group are those birds related to the proximity of the African continent. An example is the Black-winged Kite (*Elanus caeruleus*, Gleitaar). It is a rather rare bird, but its range is expanding, so we might encounter it in the coastal region.
A bird with a peculiar distribution is the Azure-winged Magpie (*Cyanopica cyanus*, Blauelster), which is rather common in open woodland. It has a disjunct area: one population in Iberia and another in eastern Asia. Ornithologists think that the explanation for such a distribution must be sought in relation to glacial history.

We will most probably encounter a variety of heron species (Reiher) in the dune area. One of our palynological sites, the Murta Valley, had a beautiful mixed colony in 1990; we hope it has not been disturbed and is still there in 1991. We saw or heard Cattle Egrets (*Ardeola ibis*, Kuhreiher), Little Egrets (*Egretta garzetta*, Seidenreiher), Purple Herons (*Ardea purpurea*, Purpurreiher), and Little Bitterns (*Ixobrychus minutus*, Zwergrohrdommel). Late in the afternoon or early in the morning we might see also Night Herons (*Nycticorax nycticorax*, Nachtreiher) and Bitterns (*Botaurus stellaris*, Rohrdommel).

A species we will certainly encounter, be it only in Alcácer do Sal, are White Storks (*Ciconia ciconia*, Weisstorch), which are still pretty common in Portugal, although also here they are declining. Additional species to be expected on the coast are Bea-eater (*Merops apiaster*, Bienenfresser), Hoopoe (*Upupa epops*, Wiedehopf) and Red-rumped Swallow (*Hirundo daurica*, Rötelschwalbe).

Birds of the Serra da Estrela

Raptors tend to be rare in Portugal, firstly because of the wet climate and small-scale landscape (not fitted for the vultures, Geier) and secondly because of hunting. But in the Serra da Estrela we most probably will encounter several species. To be expected are the following:

Booted Eagle (*Hieraäetus pennatus*, Zwergadler)
Short-toed Eagle (*Circaëtus gallicus*, Schlangenadler)
Montagu's Harrier (*Circus pygargus*, Wiesenweihe)
Buzzard (*Buteo buteo*, Mäusebussard)
Peregrine Falcon (*Falco peregrinus*, Wanderfalke)
Kestrel (*Falco tinnunculus*, Turmfalke)

We will probably also encounter a number of raptors which are very common in Spain, such as Kites (*Milvus milvus*, Roter Milan and *Milvus migrans*, Schwarzer Milan), but far more rare in Portugal.

Some of the most interesting little bird species are:

- Dipper (*Cinclus cinclus*, Wasseramsel)
- Crag Martin (*Ptynoprogne rupestris*, Felsenschwalbe)
- Rock Thrush (*Monticola saxatilis*, Steinrötel)
- Wheatear (*Oenanthe oenanthe*, Steinschmätzer)
- Stonechat (*Saxicola torquata*, Schwarzkehlchen)
- Melodious Warbler (*Hippolais polyglotta*, Orpheusspötter)
- Bonelli's Warbler (*Phylloscopus bonelli*, Berglaubsänger)
- Tawny Pipit (*Anthus campestris*, Brachpieper)
- Ortolan Bunting (*Eberiza hortulana*, Ortolan)
- Rock Bunting (*Emberiza cia*, Zippammer)

A special case is that of the Chiffchaff (*Phylloscopus collybita*, Zilpzalp). In Portugal it has two subspecies, easily to be distinguished by its song. One is the typical Iberian subspecies, which lives in the Mediterranean lowlands and is the normal form to Iberian ornithologists. The second is the central-European subspecies, which is the same as that which occurs in e.g. Holland and Switzerland. The latter is restricted to the higher parts of the Serra da Estrela and is absent from the lowlands.

Mammals

Wild mammals are rather rare in Portugal due to hunting and you see even fewer of them. The only species we will probably encounter is the rabbit (Kaninchen). Iberia has two specialties: the Pardel Lynx (*Felix lynx pardina*), which is an endemic subspecies, and the Genet Cat (*Genetta genetta*), probably introduced from Africa. Foxes (Fuchs) are pretty common. Some people say that a few years ago the Woolf (Wulf) has returned to the Serra da Estrela from the north of the country, where they are still living. It is said that they eat stray people from time to time. One of the nicer species in the Serra da Estrela is the Stone Marter (*Martes foina*), but in all those years we only saw it once at night. Also the Otter (*Lutra lutra*) seems still to be present in Portugal, but probably not in the mountains.

Amphibians and reptiles

Serra da Estrela

Portugal has a great variety of reptiles and amphibians. During the last few years we paid special attention to these animals in the Serra da Estrela. The mountain climate makes that a few more northerly species can occur here that are absent from the lowlands. These are:

Alytes abstetricans (Geburtshelferkröte), very common
Anguis fragilis (Blindschleiche), rather rare
Coronella austriaca (Glattnatter), rare

A speciality is the very common *Lacerta monticola* (iberische Gebirgseidechse), in Portugal occurring only in the Serra da Estrela and in Spain restricted to a few higher mountain regions (Sierra de Gredos, de Guadarrama and Cantabrica). Another Iberian species which is restricted to a few mountains is *Rana iberica* (iberische Braunfrosch). It is common in small, running rivulets.

Additional species we encountered in the last few years are:

Salamandra salamandra
Triturus marmoratus (Marmormolch)
Bufo bufo (Kröte), a lowland species
Bufo calamita (Kreuzkröte), lowland species
Hyla arborea (Laubfrosch), very common above the tree-limit
Rana perezi (iberische Seefrosch), very common in the lakes
Psammodromus algirus (Sandläufer), very common in lowland
Lacerta lepida (Perleidechse), very common in lowland
Lacerta schreiberi
Podarcus hispanica
Podarcus bocagei
Coluber hippocrepis
Elaphe scalaris
Natrix natrix
Vipera latasti

Lowlands

In the coastal dunes we saw still two additional species:

Psammodromus hispanicus
Acanthodactyles erythrurus

In Lisbon you might see the Gecko (*Tarentola mauritania*) on the walls, hunting insects in lamplight.

Insects

Insect life is plentiful in Portugal, but we are rather early in the season for the striking larger insects like butterflies, grasshoppers and terrifying beetles. Nice species we might see are:

Pandoriana pandora (Cardinal, Kaisermantel)
Melenargia galathea (Marbled White, Damen- od. Schachbrett)
Sphingonotus cyanopterus
Oedipoda germanica
Locusta migratoria (Migratory Locust)
Ephippiger ephippiger (a Bush Cricket)

BETWEEN A BURNING SUN AND A BIG BLUE SEA: PHANTASIES ON PORTUGUESE PEAT

by Hans Joosten

Introduction.

"Portuguese peat" almost sounds as a contradictio in terminis: Portugal is known to be a hot, arid country and peat is associated with coolness and moistness. Peat mires, however, do exist in Portugal and, as always, such "marginal" occurrences may provide some clearer insights into processes that are normally taken for granted.

Peat accumulation.

Peat[1] accumulation results when the rate of addition of organic material exceeds the rate of decay (and removal). Addition is in the first place determined by the productivity of the vegetation, in lakes near the surface, in mires at the surface. Decay, on the other hand, is most intense near the surface, but also occurs over the total peat column.

All over the world (except in arctic regions where productivity may be very low), the rate of decay is the crucial factor in peat accumulation. The decay of organic material is affected inter alia by temperature, water supply, oxygen supply, nature of the organic material, and nature of the decomposing organisms, with interacting links between all these factors. The central factor is <u>water supply</u>:

* water reduces fluctuations in temperature, due to its large heat capacity; especially levelling off high temperatures is important.
* the rate of diffusion of oxygen in (stagnant) water is to slow to replace the O_2 used in aerobic metabolism; waterlogged organic material rapidly becomes deoxygenated as a result and peat can be accumulated.

"Anywhere water collects on its way down from the catchment to the sea constitutes a template for peat formation" (Bellamy 1972). So mires (peat accumulating landscapes) must be found in "sinks" in the landscape.

Peat in time.

As long as more or less stagnant water is present, peat accumulation may occur. The process may be interrupted in two ways: by too much and by too little water. Hence we can distinguish two types of "ephemeral mires":

* "underfed sinks", where water supply is not continuous, so that waterlogging cannot be sufficiently maintained. As a consequence the peat accumulated during the wet season will decay or erode completely during dry periods. We know some beautiful lakelets in the inland Alentejo of Portugal, filled with water in spring, but dry in summer. No peat deposits can be found there.
* "overfed sinks", where water supply and its energy during some periods of the year are so great, that peat accumulated in the drier season, is removed by water erosion. Many parts of river channel systems can be considered to be overfed sinks.

From a palaeo-ecological point of view only "permanent mires" are interesting. Permanent mires are present in sinks (basins), where water supply is so constant and large, that an (almost) permanent presence of (not to fast running) water is guaranteed.

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[1] Peat is any predominantly organic deposit formed in a wet environment, nearly always in situ (Gore 1983). In this paper "peat" includes gyttjas.

The water balance of basins.

Accumulation of water in a basin is only possible when the total catchment area of that basin has a positive actual precipitation surplus. Within the catchment area there may be subareas where evapotranspiration exceeds precipitation, even on an annual base. Especially in basins in dry climates this will be the case, because actual summer evapotranspiration from a mire surface may largely exceed actual evapotranspiration from a dry surface. It may even be much larger than the potential evaporation from an open water surface due to surface roughness of the mire surface.
"Permanent" water saturation of the basin, and hence accumulation of peat (incl. gyttja), in such cases is only possible, when the basin is also supplied with water from other parts of the catchment area: the local excess of atmospheric discharge of the basin is compensated by a supply from the surrounding "field" (fig. 1.).

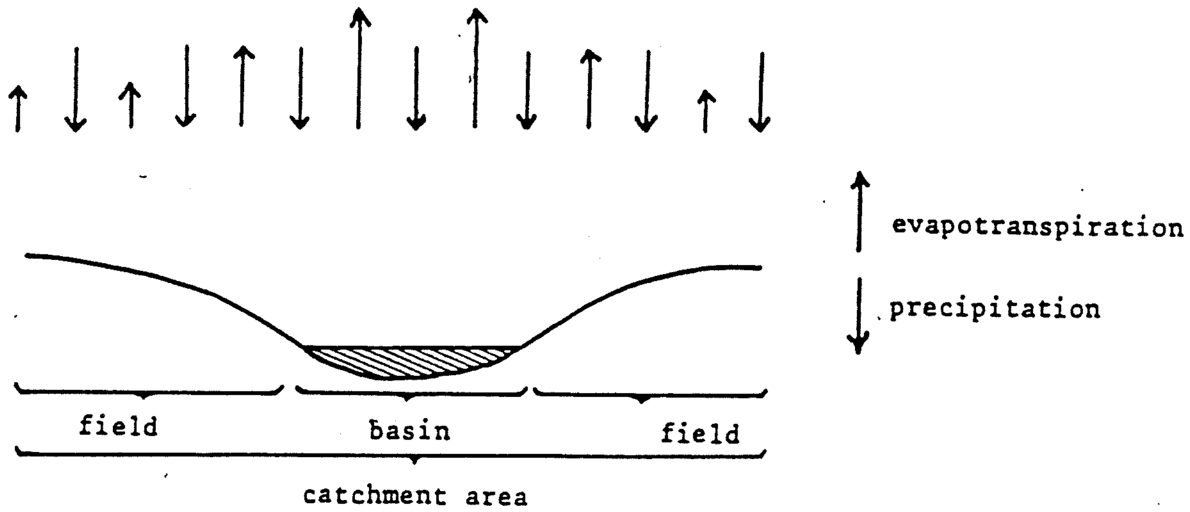


Fig. 1. A water-accumulating landscape.

It is easy to describe the water balance of a basin in hydrological terms. The basic hydrological equation is:

1. influx - efflux - $\Delta W = 0$ W = storage [m]

The influx per unit basin area [m] consists of the precipitation on the basin area itself plus the precipitation surplus from the field:

2. $\text{influx} = P + \frac{(P - E')R}{r}$

P = precipitation [m]
E' = evapotranspiration of field [m]
R = expanse of field [m^2]
r = expanse of basin [m^2]

Note that precipitation is, for reasons of simplicity, considered to be similar for the total catchment area, an assumption that will only be valid in relatively small and smooth landscapes.

The efflux from the basin per unit basin area [m] consists of evapotranspiration from the basin and of surficial and subsurface discharge:

3. efflux = E + D

E = evapotranspiration of basin [m]
D = discharge [m]

Combination of 2. and 3. in 1. yields:

4. $$P + \frac{(P - E')R}{r} - D - E - \blacktriangle W = 0$$

or:

5. $$P - E' = \frac{(D + E + \blacktriangle W - P)r}{R}$$

It is obvious from equation 5. that, if precipitation surplus of the field (P - E') is reduced, the following options result:

discharge D must decrease
evapotranspiration from the basin E must decrease
storage ▲W must decrease
precipitation P must increase
expanse of the basin r must decrease
expanse of the field R must increase,
or any combination of these options.

Let us take a closer look at these possibilities.

A reduction of the area of the basin (r) in order to decrease evapotranspiration from the basin will be dangerous from the peat's point of view. In the dry parts the peat will oxidize rapidly because water saturation is no longer guaranteed. For shorter periods, it might be a solution for the mire.
The increase of precipitation (P) is improbable when P - E' is reduced. A reduction of evapotranspiration in the basin (E) is also unlikely, because E will almost always approach or exceed the potential evaporation as a result of the necessarily water saturated surface of the basin. Evapotranspiration might be reduced by a superficial dessiccation of the basin, but this may only happen temporarily because of the resulting increased decay of the accumulated organic material. E might also be diminished by inundation of the mire surface, or by a deforestation of the basin. These options, however, are hardly probable in the drier conditions that result from a decreasing precipitation surplus.

The remaining area of the field (R), change in storage (▲W) and disposal (D) concern three different spatial units, the field of telluric supply, the field of telluric discharge and the basin itself:

D depends on the characteristics of the field of discharge and on that of the basin
▲W depends on the characteristics of the basin
R only depends of the field of supply.

Let's first consider the recharge to and discharge from the basin.

<u>The position of the basin.</u>

In a given precipitation surplus, permanent water saturation and hence peat accumulation are determined, according to equation 5., by the quantity of field supply, being proportional to the expanse of the field. Or: in decreasingly favourable climatic conditions we only may expect mires in basins with an increasing field expanse (fig. 2.).

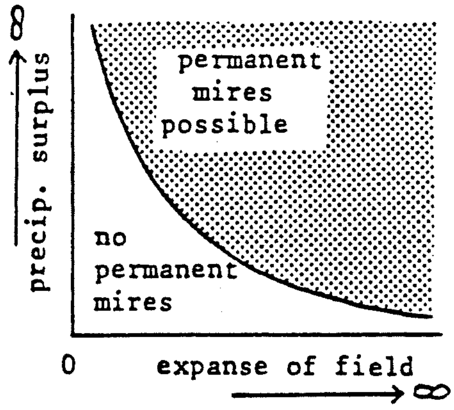


Fig.2. Hypothetical relation between peat accumulation possibility, precipitation surplus and expanse of field of telluric supply.

The most extensive "field" in a given catchment is, of course, present in or closely near the ultimate sink of the catchment. Since the ultimate sink of all water on earth is the ocean, one may expect peat mires in the least favourable climatic conditions
only close to the ocean. Examples of this phenomenon are the coastal mires of Senegal (Pajunen 1984, Korpijaakko 1985), and southeast Australia (Campbell 1983, Shier 1985).
In Portugal, coastal mires and peat deposits are found in two not always absolutely separable types of landscapes (Zbyszewski 1980):

* lakes, isolated from the sea by dunes and sand beaches, e.g. Lagoa Travessa, Lagoa Formosa, Lagoas do Barbaroxa between Setúbal and Sines in the Alentejo region (Matéus 1989, Joosten & Janssen 1986)
* river estuaries draining "freely" into the ocean, where favourable conditions for peat accumulation are found in quiet bays and branches and abandonned river meanders, e.g. Lagoa de Albufeira/Estacada near Setúbal (Queiroz 1989), Vale de Figueira, Lagoa de Melides and Lagoa de St. André.

Portuguese coastal peatlands have been reported from the regions of Oporto (Elhai 1964), Aveiro, Obidos, Setúbal, south of Comporta, between Melides and Sines and from the Algarve (Zbyszewski 1980).
In a palaeoecological study, Matéus (1989) has shown the close hydrological interrelations between the coastal mire Lagoa Travessa and its surrounding upland "field". In the Lagoa de Albufeira region similar hydrological phenomena were observed (Queiroz 1989).

A larger "field" not only has a quantative advantage: because of the varying distances to the basin and the differences in soil conditions, geomorphology and geology in the area, the water supply to the basin may be more evenly distributed and fluctuations in precipitation surplus may be levelled.
As precipitation surplus increases and becomes more evenly spread, permanent water saturation of the mire/basin will be possible at a larger distance from the ultimate sink, i.e. the supplying field can be smaller, as is shown in fig. 3.

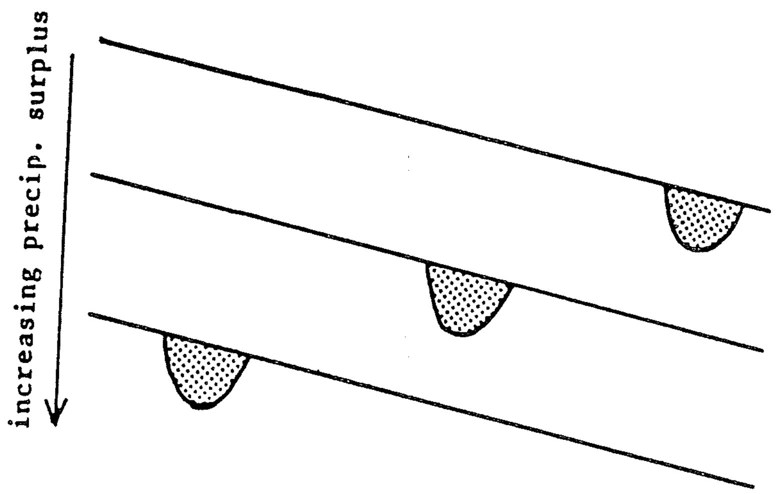


Fig.3. Position of a mire basin in relation to precipition surplus.

At lower altitudes in mountains precipitation surplus will be smaller than at higher elevations, mainly because of increased evapotranspiration as a result of increased temperatures. This enables us to use altitude as a rough estimate for local precipitation surplus. In Table 1. we present the altitudes of the mires in the Serra da Estrela, with the approximate expanse of their catchment areas and the depths of their peat deposits. From fig. 4. we may conclude that the distibution fits the theoretical model rather well: the lowermost mires (Candeeira, Vale do Rossim) have the largest catchment areas, while at the highest altitudes catchment areas may be very small.
But even at the highest altitudes in the Serra it is improbable to find mires without an external supplying field. Climatic conditions apparently do not favour the development of bogs, although as a result of small catchments and poorly weathering acid rocks, mire vegetation may sometimes give a rather "ombrogenous" impression.

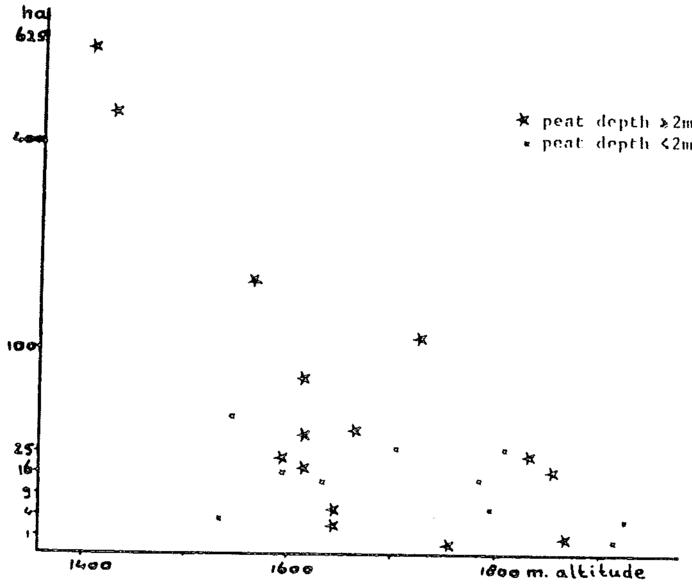
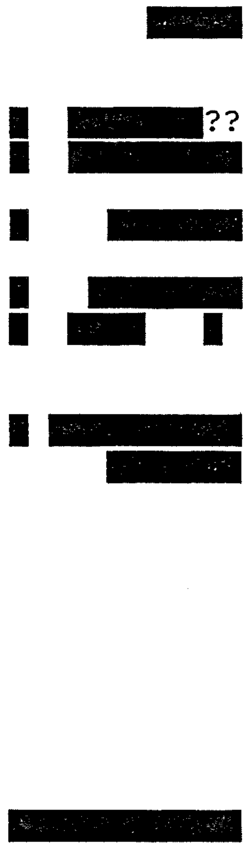


Fig.4. Altitude and catchment area expanse of mires in the Serra da Estrela.

Table 1. Altitude, catchment area expanse, peat depth and age of deposits of mires in the Serra da Estrela (Portugal).

code	altitude (m)	catchment area (ha)	peat depth (m)	age of present deposits (10^3 y BP) 111 210987654321
Torre	1925	3	1.4	
Torre 2	1915	0.5	1.6	
Torre 3	1868	0.7	2.1	
Lagoa Clareza 1	1855	16	7.3	??
Lagoa das Salgadeiras	1832	22	4.0	
Clareza 89 mire	1810	26	1.0	
Charca dos Cões 2	1795	5	1.6	
Charca dos Cões	1785	13	1.2	
Chafariz do Rei	1755	0.3	2.8	
Covão do Boieiro	1725	108	8.7	
Peixão mire	1705	26	0.9	
Lagoa do Peixão	1665	36	?	
Lagoa Comprida 2	1645	5	4.5	
Lagoacho das Favas	1645	2	6.3	
Lagoa dos Cântaros	1635	12	1.0	
Lagoa Redonda	1615	34	>5	
Lagoa Seca	1615	18	5.6	
Covão Cimeiro	1615	73	4.6	
Lagoa Comprida 1	1595	22	5.3	
JHV	1595	15	1.2	
(Covão de Ferro)	1575	175	?	
Nave de Santo António	1545	43	0.6	
Mourisco	1535	3	1.6	
Vale do Rossim	1425	451	>1.0	
Candeeira	1405	590	11.9	



<u>The shape of the basin.</u>

Equation 5. also points to the importance of storage. Storage in this equation actually is identical with water level. Lowering the water level (decreasing storage) is a last possibility to balance the water budget when atmospheric and telluric supply are becoming deficient.
The first step in this process is the lowering of the water level to the plane on which surficial disposal stops ("weir level"). As surficial disposal mostly is a quick process, this point will be reached soon after mire evapotranspiration exceeds atmospheric and telluric supply. From that moment on evapotranspiration surplus will start to lower the water level in the basin until supply exceeds the "atmospheric disposal" again. How much the water level drops depends on

- # the "cumulative supply deficit": the cumulative difference between evapotranspiration (and possible subsurface disposal) and atmospheric and telluric supply (note here the importance of seasonal variability of the climate!)
- # the hydraulic properties, e.g. the storage capacity, of the basin filling "deposits".

A deeper basin enables the accumulation of peat for a longer period, because accumulating peat deteriorates its own growing conditions by a gradual reduction of the storage capacity of the basin by changing "open water" into a deposit with a smaller storage capacity.
The most succesful peat accumulating basins in the Serra are the deeper lakes in which open water communities have built deposits of gyttja. Beautiful examples are the Charco da Candeeira, of which the 14 m thick deposits almost completely consist of gyttja, the Lagoa Comprida 1 and 2 sites, and the Covão do Boieiro.

The pollen diagrams of many sites show, that during the open water phases of peat accumulation similar aquatic vegetations may have been involved that are still present today in the area. Local succession, as revealed from palaeoecological studies, even show a pattern, consistent to that observed in the present zonation from the centre of a lake to its margins. Deep water vegetations with *Potamogeton* (*polygonifolius*) (and sometimes *Menyanthes*), shallow water vegetations with *Sparganium* (*angustifolium*), Gramineae (*Antinoria agrostidea* ssp. *natans*) and *Ranunculus* sect. *Batrachium*. *Fontinalis antipyretica* can be found growing on rocky outcrops in this zone. Still drier is the zone with Cyperaceae (especially *Carex nigra*).

During the phase with *Antinoria* and *Ranunculus* the basin is filled to a level that the lake dries up temporarily.

Oxidation of reduced sulphur and nitrogen components may then lead to acidification and to the establishment of species like *Juncus bulbosus*, *J. tenageia*, *J. effusus*, *Sphagnum cuspidatum* and *Drepanocladus fluitans* (and even *Molinia caerulea* and *J. heterophyllus* as in the Vale da Candeeira).

In such filled-up basins the same quantity of evapotranspiration will lead to lower water levels with increasing oxidation of the peat deposits than in the former lakes.

This oxidation leads to decreasing pore volumes in the herbaceous peat and therefore to a decreasing storage capacity, resulting in even lower water levels and even larger fluctuations of the water level etc. etc...

However, this process, that is on the long run a menace to the preservation of the peat deposits, can be for a shorter term beneficial: the "self intensifying" process eventually is slowed down, because decreasing pore volumes reduce the capillary fluxes, and actual evapotranspiration decreases. The dried-out upper layers protect the deeper deposits from desiccation and oxidation.

As long as annual "peat production" at the surface in wetter periods exceeds peat oxidation during dry periods, peat accumulation will continue. The peat will however be strongly oxidized, humified and compact and will have a small storage capacity.

The typical present-day vegetation on this substrate is the Junco-Sphagnetum compacti.

This vegetation type is characterized by *Nardus stricta*, *Juncus squarrosus*, *Potentilla erecta*, *Gentiana pneumonanthe*, *Pedicularis sylvatica*, *Carex echinata*, *Carex nigra*, *Viola palustris*, *Narcissus bulbocodium*, *Drosera rotundifolia*, *Wahlenbergia hederaceae*, *Polygala serpyllifolia*, *Sedum anglicum*, *Galium saxatile*, *Sphagnum compactum* (*Sphagnum* nomenclature according to Daniels & Eddy 1985), *Polytrichum commune* and *Aulacomnium palustre* (e.g. Pinto da Silva & Teles 1980; Braun-Blanquet et al. 1952). Next to *Sphagnum compactum*, that can be found at all altitudes in the Serra, the following *Sphagnum* species have been observed in this type of vegetation: *Sphagnum palustre* (Lagoa Redonda), *Sphagnum capillifolium* (incl. var. *rubellum*), *Sphagnum russowii*, *teres* and *flexuosum* (all on a slope northeast of Lagoa Comprida, 1700 m), *Sphagnum girgensohnii* (Lagoa das Salgadeiras), *Sphagnum auriculatum* (on several wet spots), and *Sphagnum angustifolium* (Lagoa Redonda and southeast of Lagoa Seca).

It is not unlikely that the vegetation contains a large number of "natural" elements, although the occurrence of this vegetation type, like all other "Nardo-Galion"-communities, will have been strongly stimulated by thousands of years of grazing. The fact is, that ("anthropogenic") trampling on peaty substrates will have the same effect as the naturally strongly fluctuating water levels in the Serra: a severe compaction of the soil. In the diagram of Salgadeiras we may observe a simultaneous expansion of both *Galium* and *Potentilla* around 5700 BP. In other diagrams, Nardo-Galion communities only start to establish and/or expand much later, when human interference with natural vegetation in the Serra is obvious.

In the Torre diagram these vegetations with *Narcissus*, *Potentilla*, *Gentiana* and *Pedicularis* prove to have been present right from the start of peat formation. Probably this mire even originated as a result of grazing, as is pausible from the presence of a *Betula* peak in the lower part of the pollen diagram. This might point to the possibility mentioned before: a decrease of evapotranspiration from the "field".

Discharge from the basin.

As we have seen, the discharge D depends on the characteristics of the field of discharge and on that of the basin. Normally these characteristics can be regarded as being constant in time. One big exception of this rule is ... peat formation.
The accumulation of peat can be considered as the formation of a dam in the landscape. As a result, upward parts of the "field" may "paludify" and the mire may expand: the "secondary mire systems" of Moore & Bellamy (1974). On a small scale we may see this proces near the Torre summit, and at the Clareza mires. Beautiful examples also occur northeast of Lagoa Comprida. A special feature of these "sloping mires" are their surface patterns: pools of open water seperated by peat walls.
The development of such patterns is not as strange as it might look. Swanson & Grigal (1988) showed in a simulation model that these "string-and flark" patterns originate when
1) the hummocks impede the flow of water across the surface more than hollows do,
2) hummocks expand and hollows shrink when water levels drop,
3) a critical minimum surface slope is present, and
4) the supply of water to the mire is sufficient to prevent the mire surface from being dominated by hummock-level conditions.
Conditions 1) and 2) are met in the Serra, where "drier" vegetations build a more compact and less permeable peat. Condition 3) will never be a problem in a mountainous area. Condition 4), however, brings us back to the old problem of the burning sun and the big blue sea: sufficient supply (and its complement: limited evapotranspiration) in Portugal will only be found high in the mountains. And that is just where we find these "patterned mires".

The patterned mires have found and founded their basis and basin on peat: a risky business in a warm climate. How long they can keep their head under water, only time can learn. We palaeo-ecologists, however, may find comfort in the awareness, so strikingly expressed by the Rolling Stones (!) long before we had even discovered the Serra da Estrela: time is on our side...

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A PRELIMINARY PALYNOLOGICAL STUDY OF PEAT DEPOSITS NEAR AN OPPIDUM IN THE LOWER TAGUS VALLEY, PORTUGAL

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SUMMARY

Pollen analysis of peat cores in a narrow and in a wide valley adjacent to an oppidum south of the village of Alpiarça, where numerous artifacts from prehistoric times are known to exist, reflect a relationship with the human occupation on the hill. The most intensive relationship with the activities of man is shown in the pollen assemblages from the narrow valley. Here the sampling site is close to the oppidum and the pollen assemblages have a clear local and extralocal character. In contrast the pollen assemblages from the core in the wide valley from a site at a greater distance to the oppidum have a more regional aspect. From the contrast between the local and regional pollen assemblages the influence of man on the vegetation nearby can be ovaluated.

All the pollen diagrams show from the bottom to the top of the core a decrease in the pollen values of *Pinus*, later also of that of *Quercus*, while the values of the nonarboreal pollen types increase.

The pollen diagrams from the n arrow valley, covering the time between at least 5000 BP and 2000 BP, according to four radiocarbon dates, show at several levels a decrease of the pollen values of *Pinus* and *Quercus* when the non arboreal pollen percentages show maximum values, especially those of *Plantago, Echium, Spergularia,* taxa that also taday are abundant on abandonned fields. Also pollen of *Vitis* has maximum values at these levels.

The deposits in the two valleys offer an excellent opportunity to study the influence of men's activities on the vegetation of an area small in extent, that was occupied in prehistoric and historic times. Such a study will be enhanced greatly by excavations by the Instituto Arcueologio Alemão, Delegação em Portugal.

INTRODUCTION

In 1980 the Instituto Arcuelogico Alemão (IAA), Delgação em Portugal, conducting archeological excavations near Alpiarça (Kalb and Höck, 1980), directed our attention to a steep, ca 20 meter high hill, south of the village of Alpiarça, an important site for the Copper Time in Portugal.

The Alpiarça site is, unlike other sites from that period in the Lower Tagus valley, relatively undisturbed by previous excavations. Accordingly promising excavations went underway in the following years.

In 1980 peat deposits were discovered underneath the disturbed top layer of the sediment in two valleys bordering the hill to the north and to the south. It looked promising to connect the development of the vegetation in this area with the history of habitation of the hill.

The present paper reports on preliminary palynological analyses of two cores. The primary aim of this preliminary study was to see whether palynological research in connection with the archaeological excavation is worthwile. Accordingly, counting of pollen was done on a low level of resolution, with a rather wide sampling interval and with rather low pollen sums.

LOCATION OF THE CORES

Fig. 1 shows the location of the Alpiarça hill. To the north and south side valleys of the river Tagus are incised in terrace materials from the Pleistocene (Zbyszewski, 1953: carta geológica de Portugal, Folha 31-A, Santarém). The geological map also shows the location of rice fields in the two valleys. Today all cultivation of rice ceased and most of the area of the two valleys has turned into swamps and meadows. The hill thus is surrounded and protected on three sides by low lying terrain. On the eastern side, however, nu such protection was available and here a curved artificial earthen wall was built in prehistoric times.

One core (Alpiarça I) was taken in the broad southern valley, the other (Alpiarça II) in the narrow northern valley. Both cores show an alternation of clay, clayey peat, peat and wood. The general lithology is shown on the left hand side of the two pollen diagrams (figs. 2 and 3).

RESULTS

Cultural phases connected with habitation are of course best reflected in the upland vegetation development. The pollen values are therefore expressed in percentages based upon an upland pollen sum comprising pollen types from plant species that were never part of swamp vegetation. The pollen values are shown in two pollen diagrams (figs. 2 and 3), each including a summary diagram and a number of separate specific pollen types, chosen from the total number, because these exhibit the most interesting trends.

In both cores the number of pollen of swamp vegetation far out number those of the upland. The upland pollen sum is often too small to prevent irregular fluctuations in the curves of some of the pollen types. The general trend of the pollen curves of upland plant species is, however, clear. Both diagrams show in different degrees from bottom to top of the core a decrease of the values of pine (*Pinus*) and oak (*Quercus*) and an increase of the values of the NAP (total upland non-arboreal pollen), Changes in the proportion of arboreal pollen (AP) and non-arboreal pollen (NAP) depict in general changes in the degree of forestation of a REGION. The pollen trends thus suggest a change on the surrounding upland from open forest - or perhaps more likely (oak) savanna - to a more open landscape of steppe/ruderal vegetation and heather. This picture agrees with the observation from the montane zone of the Serra da Estrela (Janssen and Woldringh, 1981 and V.d.Brink and Janssen, in press) some 150 km towards the northeast. The 14C dates at Casos dos Pátudos indicate that the demise of pine and the expansion of heather took largely place in Mid-Holocene times between 4.000-5.000BP (years before present).

We consider especially the trends in the curve of pine an excellent tool to trace synchroneous horizons in cores from two regions because of the general good dispersal capacities of pollen of pine. The trends in the curve of pine therefore may reflect changes in the vegetation of a large area.

In contrast pollen of heather reflect, unlike pine, usually changes in the vegetation on a much more local scale.

Similar dates for the decrease of pine and the expansion of heather are available for the Serra da Estrela, where the change from forest vegetation to heather was interpreted as a result of grazing and burning. This general decrease of pine and increase of heather is also shown in recent palynological work in the coastal area south of Lisbon (Mateus, mscr.; Queiroz, mscr.). It is possible that similar activities took place at Alpiarça. If so, then the deposits contain an excellent record of these activities, not in general, but here connected with the activities of a small sample of the human population, viz. the habotation on the hill.

In some more detail the pollen diagram Alpiarça II shows at the base (Spectrum Nr. 2, 3) already a maximum of the values of the NAP (for instance plantain, *Plantago*, and vine, *Vitis*), after which forest vegetation (oak and pine) expanded at the expense of the NAP (Spectrum No. 4-7). After 5.000 years BP forest elements decrease in value and the values of the NAP increase again (Spectrum Nr. 8-14), culminating in the almost total absence of pollen of pine and maximum NAP values around 4.600 years BP. The very low values of pine indicate that most pollen grains of pine were transported over long distances and that pine was very rare indeed around the site. The NAP values remain generally at a high level from Spectrum Nr. 15 to 25. Around Spectrum Nr. 20-21 there is a decrease in the pollen values of heather and alder (*Alnus*), indicating a change of the vegetation on the uplands (reduction of heather vegetation) as well as in the lowlands (replacement of alder carr by *Myrica* carr). It is possible that the pollen assemblages at these levels reflect a change in the vegetation induced by the habitation pressure of the population on the hill. Additional more detailed pollen analyses may highlight this important phase in the history of the hill.

At Spectrum Nr. 25 there is a renewed increase in the values of heather and maximum values of plantain and bugloss (*Echium*). The C14 date of this level is 3240 BP.

In the upper part of the Alpiarça II diagram the pine values remain very low; also the values for oak decrease steadily. The NAP reaches maximum values, especially vine (33%) and the first presence of pollen of olive (*Olea*) is observed around Spectrum Nr. 30, 31. The 14C date here is 2590 BP.

These changes in the pollen values suggest changes in the proportion forest/non-forest, induced by activities of man. Do these high values indicate cultivation of vine or are plants of wild vine (*Vitis sylvestris?*) near the sampling site the origin of these pollen grains? It is striking that maximum values of pollen of vine are present during phases of minimum values of tree pollen (Spectrum Nr. 2,3; 11-19; 21-25; 29-31) suggesting that the plants involved belonged to vines in rather open areas. Surface samples from vineyards in the Alsace (Janssen, 1981) show very low values for vine. However, the landscape in the lower Tagus valley shows during the time span covered by the pollen diagram a much more open character than that in the Alsace and it is possible that the vine percentages are high under conditions where the total pollen production is low. Another complication is the problem of pollen transport. In the Alpiarca diagram, pollen of vine is rare, indicating, just like in surface sample studies, that it is not windblown over larger distances. Certainly the distance coring site - hill is much shorter at Alpiarça II than at Alpiarça I, there is also the possibility that much of the vine pollen grains at Alpiarça II where clay is a constant component of the deposit, is transported by water during erosional processes on the hill side. Similar considerations apply, of course, also to other upland pollen types; the solution of these problems must await the analysis of other cores with vegetation development under different environmental conditions.

Historical time is not presented in the present diagrams because the tremendous increase of pine and olive, so obvious in pollen spectra from Medieval Time on (Coudé-Gaussen and Denèfle, 1980; V.d.Brink and Janssen, 1981) is absent. This time span may be present in the (not yet analysed) upper peat deposits at Alpiarça II.

A few words must be said on the development of the local swamp vegetation in the two valleys. At Alpiarça II there is relatively little change in the development of the local swamp vegetation. The pollen assemblage indicate an alder (*Alnus*) swamp forest except between Spectrum Nr. 21-26, where pollen values of alder are relatively low and those of bog-myrtle (*Myrica*) and loosestrife (*Lythrum*) are high. The pollen diagram Alpiarça I from the wide southern valley shows bigger changes in the development of the local vegetation. The pollen zones shown in this diagram are based on the local successions: in the lower part of the Alpiarça I diagram two phases of open water are indicated by maximum in the curve of quillwort (*Isoëtes*). These two phases are separated by a phase dominated by sedge (Cyperaceae) vegetation.

In the upper part of the Alpiarça I diagram a swamp forest phase with alder, alder-buckthorn (*Frangula*) and bog-myrtle is preceded and followed by fern and sedge vegetation.

ACKNOWLEDGEMENTS

We thank Dr. W.G. Mook, Isotope Physics Laboratory, Groningen, for dating of our levels of Casos dós Pátudos and Dr. Ph. Kalb and M. Höck, Deutsches Archäologisches Institut Lisbonne, for their in many ways helpful assistance during fieldwork.

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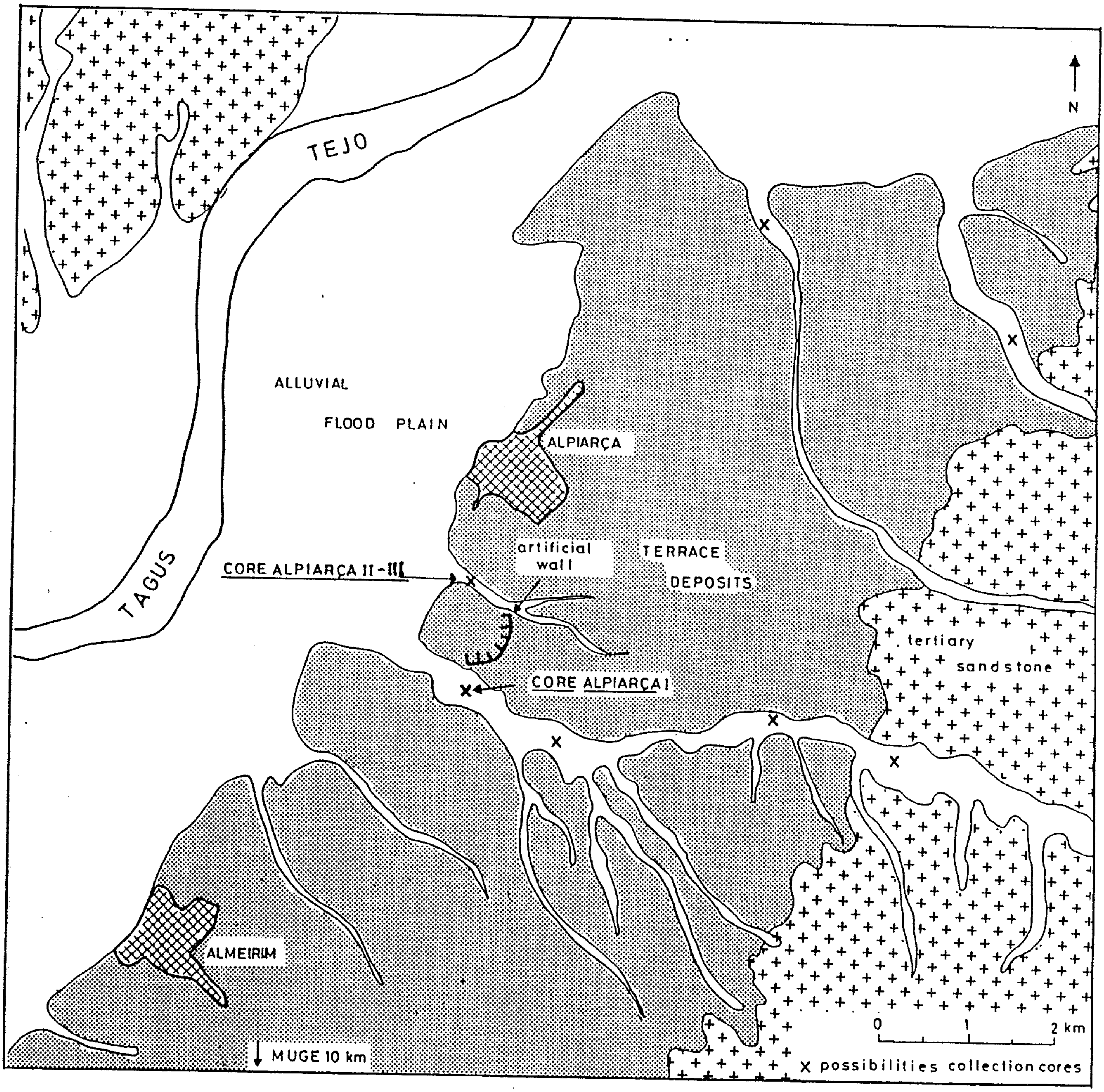
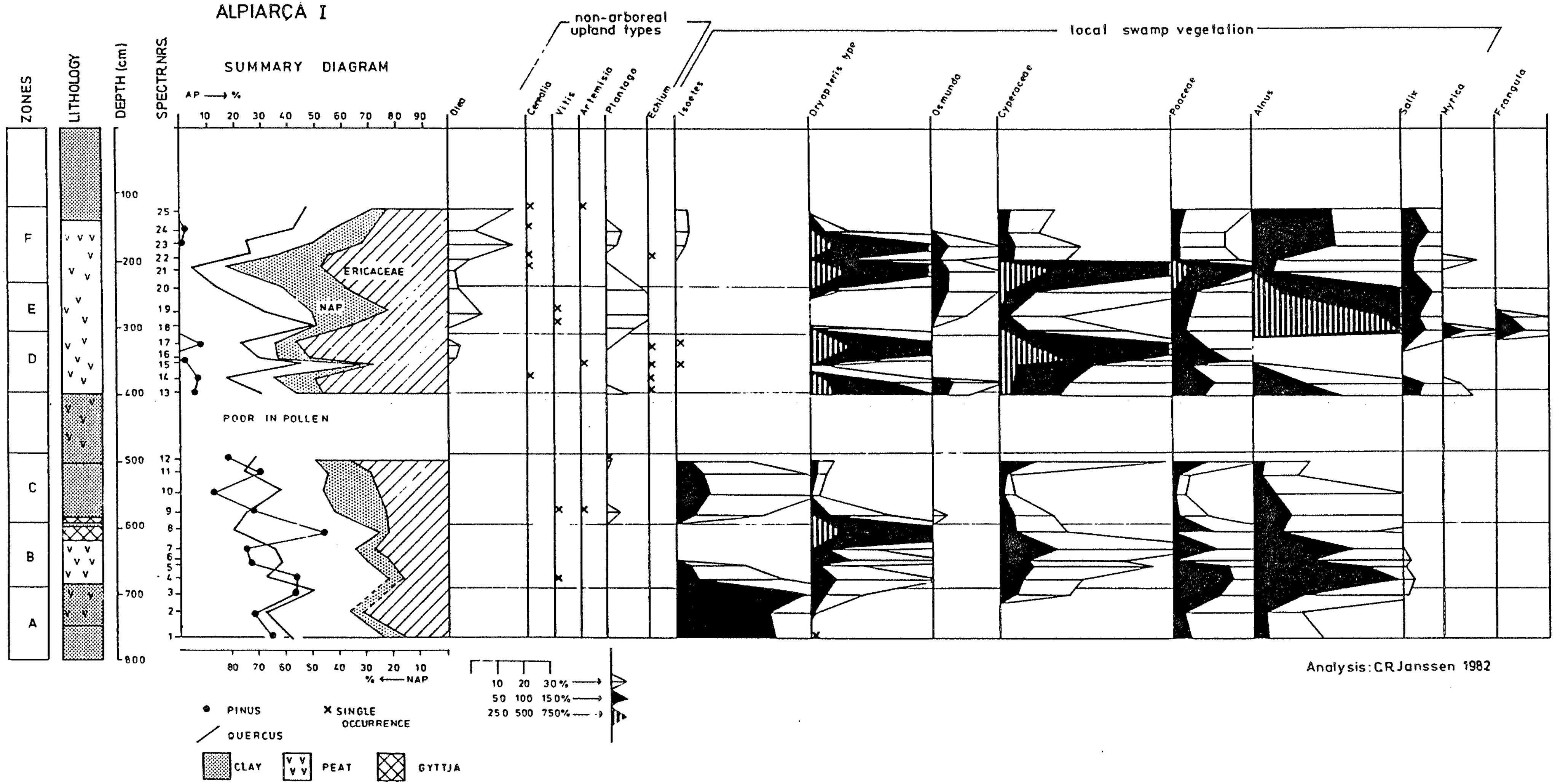
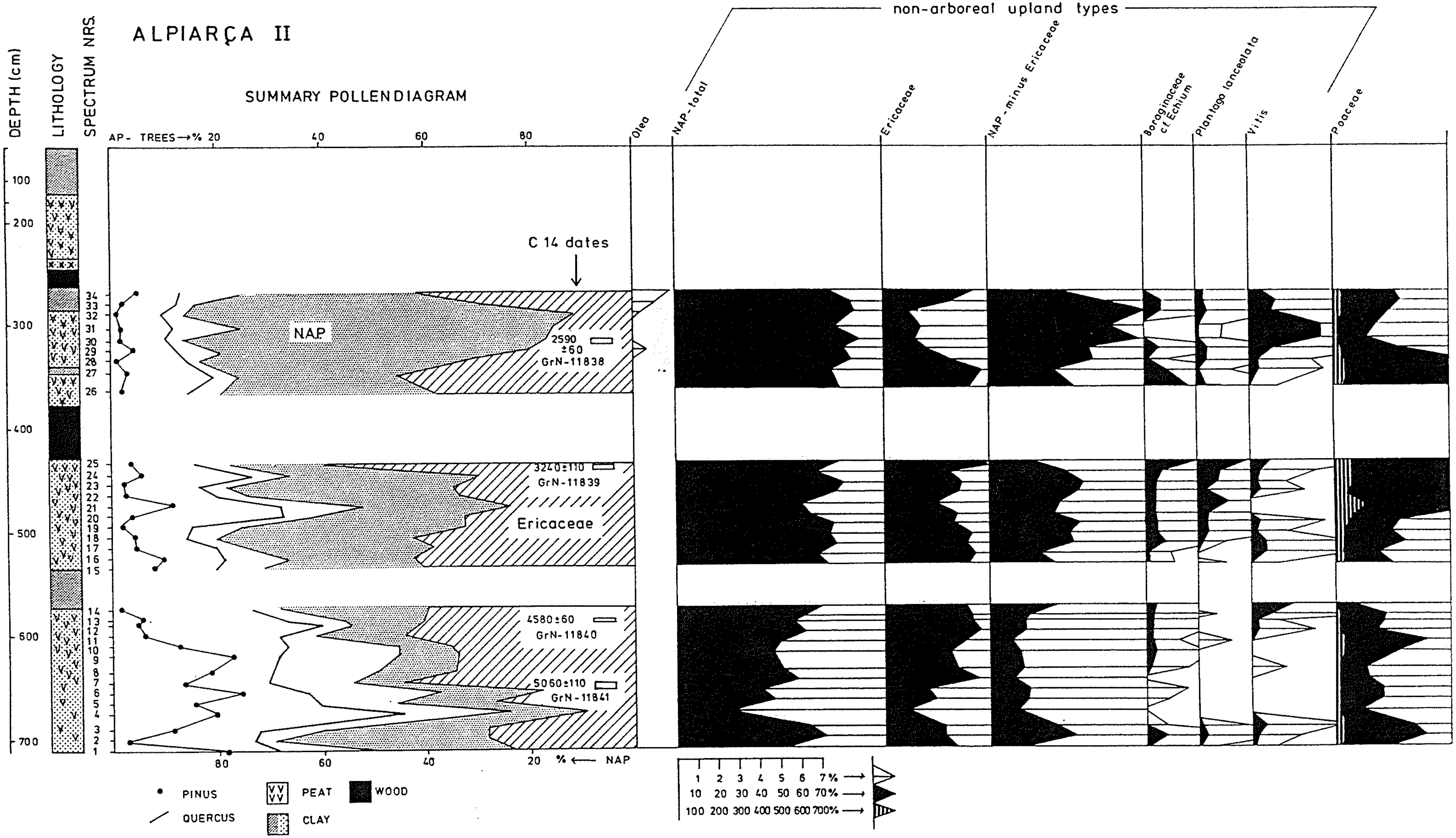
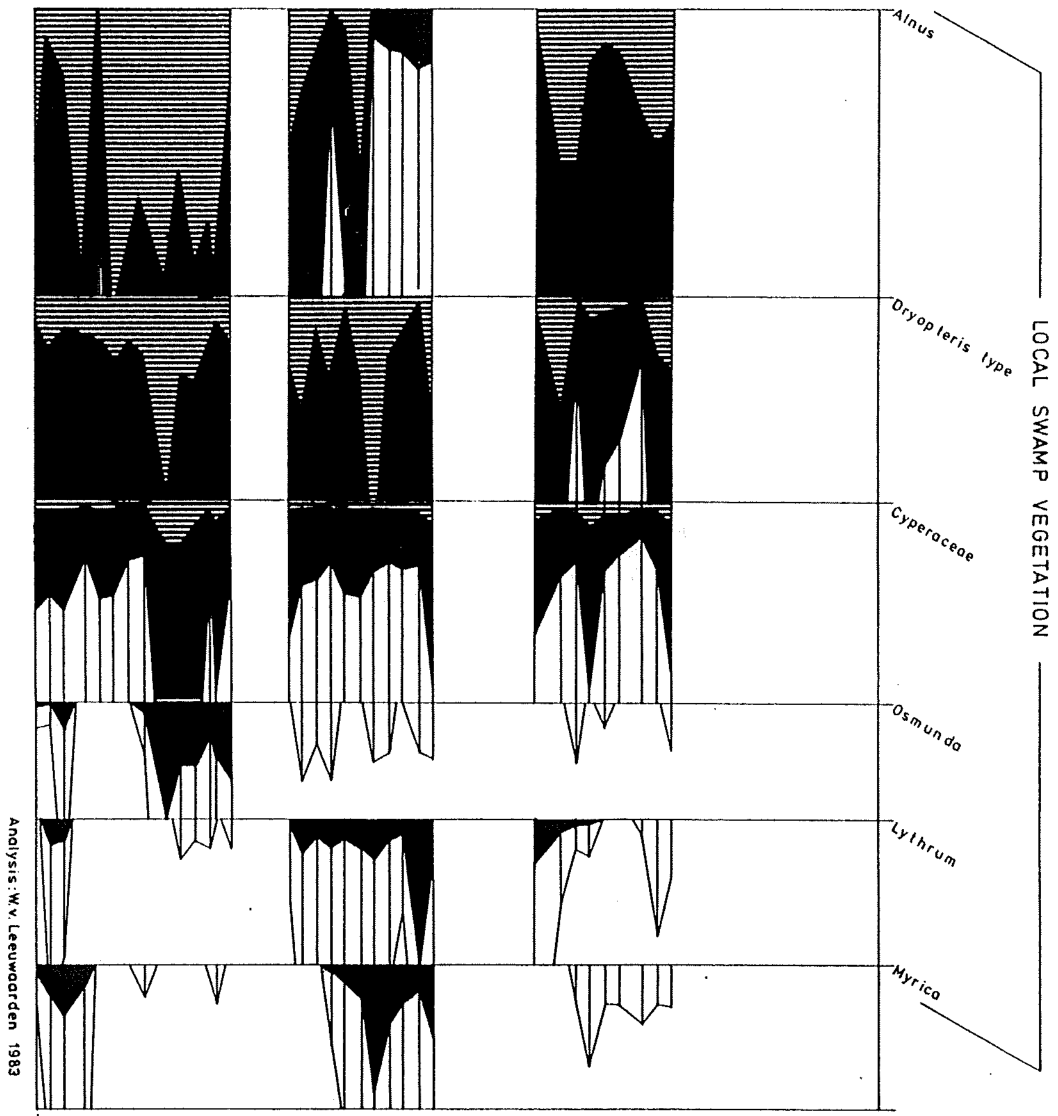


N
TEJO
TAGUS
ALLUVIAL
FLOOD PLAIN
ALPIARÇA
artificial wall
TERRACE
DEPOSITS
CORE ALPIARÇA II-III
CORE ALPIARÇA I
tertiary
sandstone
ALMEIRIM
MUGE 10 km
0 1 2 km
x possibilities collection cores



ALPIARÇA I
SUMMARY DIAGRAM
non-arboreal upland types
local swamp vegetation
ZONES
LITHOLOGY
DEPTH (cm)
SPECTR.NRS.
AP ⟶ %
Olea
Cerealia
Vitis
Artemisia
Plantago
Echium
Isoetes
Dryopteris type
Osmunda
Cyperaceae
Poaceae
Alnus
Salix
Myrica
Frangula
ERICACEAE
NAP
POOR IN POLLEN
% ⟵ NAP
PINUS
QUERCUS
× SINGLE OCCURRENCE
CLAY
PEAT
GYTTJA
10 20 30 %
50 100 150 %
250 500 750 %
Analysis: C.R.Janssen 1982


ALPIARÇA II
SUMMARY POLLENDIAGRAM
DEPTH (cm)
LITHOLOGY
SPECTRUM NRS.
AP - TREES → % 20 40 60 80
C 14 dates
NAP
Ericaceae
2590 ±60 GrN-11838
3240±110 GrN-11839
4580±60 GrN-11840
5060±110 GrN-11841
80 60 40 20 % ← NAP
PINUS
QUERCUS
PEAT
CLAY
WOOD
non-arboreal upland types
Olea
NAP-total
Ericaceae
NAP-minus Ericaceae
Boraginaceae cf. Echium
Plantago lanceolata
Vitis
Poaceae
1 2 3 4 5 6 7% →
10 20 30 40 50 60 70% →
100 200 300 400 500 600 700% →


Alnus
Dryopteris type
Cyperaceae
Osmunda
Lythrum
Myrica
LOCAL SWAMP VEGETATION
Analysis: W.v. Leeuwaarden 1983

ALPIARÇA III - VALE DO FORNO

LITHOLOGY

0 - 155 clay
155 - 700 peat
700 - 725 clay with peat
725 - 860 clay

ORGANISATION OF THE POLLEN DIAGRAM

The pollen diagrams include only the most important pollen types.
They are subdivided into two parts:
- Diagram with pollen of upland taxa
- Diagram with pollen of lowland taxa

Upland pollen diagram

Upland pollen types have been arranged into four groups:
- pollen of trees
- pollen of shrubs belonging to high maquis
- pollen of shrubs belonging to low maquis
- pollen of herbs which are assumed to originate from open vegetation

Lowland pollen diagram

The lowland pollen diagram includes pollen types of aquatic taxa and hygrophilous taxa, generally considered to grow in direct contact with the groundwater.

POLLEN SUM

The pollen sum includes all upland types. Pollen of local aquatic and hydrophilous plants are excluded from the pollen sum.
Chenopodiaceae and *Polygonum aviculare*, although of regional origin, were also placed in the lowland pollen diagram, because they are considered to have been part of the vegetation of salt-marshes in the area; probably in the Tejo river valley. These two types were excluded from the pollen sum.
The trends of *Hedera*, *Vitis* and *Lonicera* pollen show a strong correlation with those of taxa growing in alder carr; therefore these pollen types were also exluded from the pollen sum.

ZONATION OF THE POLLEN DIAGRAMS

Upland and lowland pollen diagrams have been independently zoned.

A. Zonation of upland pollen diagram

zone A: *Pinus-Quercus* assemblage zone, with *Pinus* pollen values of 15-50%; *Quercus*-deciduous pollen values of 15-50%; high pollen values of Chenopodiaceae and *Polygonum aviculare*, *Erica scoparia* pollen values low.

zone B: *Quercus-Pinus* assemblage zone, with *Pinus* pollen values of 10-25%; *Quercus* deciduous pollen values of 22-45%; *Erica scoparia* pollen values 20-50%; Chenopodiaceae and *Polygonum aviculare* pollen with low values or absent.

zone C: Low maquis-*Quercus* zone, with *Pinus* pollen constantly present with low values (max. 10%); *Quercus*-deciduous pollen values of 5-25%; *Myrtus* pollen constantly present with values of 5-12%; *Rumex acetosella* pollen values 10-20%; *Erica scoparia* pollen shows strongly fluctuating values which are more or less positively correlated with the values of *Quercus* deciduous pollen and negatively correlated with pollen values of *Rumex acetosella* and *Anthemis* type.
On the basis of these characteristics a subdivision into subzones is possible:
C1: *Erica scoparia* pollen shows a minimum, that of *Rumex acetosella* and of *Anthemis* type a maximum.
C2: *Erica scoparia* pollen shows a maximum of 45%; pollen of *Rumex acetosella* and *Anthemis* type show low values.
C3: *Erica scoparia* pollen shows a maximum, low values of *Rumex acetosella* and *Anthemis* type.
C4: *Erica scoparia* pollen shows low increasing values, decreasing pollen values of *Rumex acetosella* and *Anthemis* type.

zone D: *Olea-Sambucus nigra* assemblage zone, with *Pinus* pollen almost absent; *Quercus*-deciduous pollen shows low values (5-20%); *Olea* pollen values 5-12%; *Sambucus niger* pollen up to 30%; *Ulmus* and *Castanea* pollen present.

B. Zonation of lowland pollen diagram

zone LA: high *Isoëtes* spore values, pollen/spore values of *Alnus* and of *Dryopteris* low.

zone LB: high pollen/spore values of *Alnus* and *Dryopteris*, low spore values of *Isoëtes* and spores of *Osmunda* constantly present (10%).

zone LC: high *Alnus* pollen values, *Dryopteris* with low spore values and *Vitis* pollen constantly present.

zone LD: *Myrica* pollen and pollen of *Lythrum* present; *Alnus* pollen shows two minima separated by one very high maximum; therefore this zone can be devided in three subzones:
LD1: low *Alnus* pollen values , pollen of *Myrica*, *Lythrum* and *Frangula* present.
LD2: *Alnus* pollen values very high (600%), *Myrica* pollen values low (5%), pollen of *Frangula* and *Lythrum* with very low values or absent.
LD3: *Alnus* pollen values low, *Frangula* pollen present, *Lythrum* and *Myrica* pollen show rather high values.

zone LE: *Alnus* pollen with high values, *Dryopteris* spores present with 20-60%, *Hedera* pollen values up to 10% and *Vitis* pollen present with low values. Cruciferae with high pollen values.

zone LF: *Alnus* pollen with high values, *Dryopteris* spores show very low values (6%). High pollen values of Cruciferae.

DISCUSSION AND INTERPRETATION OF THE POLLEN ZONES

A. Pollen zones in upland pollen diagram

zone A

From a comparison between the Alpiarça II and III diagrams (ALP II and ALP III), it is obvious that the lower zone of ALP II is synchronous with zone A of ALP III. Zone A is therefore dated from ca. 5000 to 4200 BP. This period is at Lagoa Travessa a transgression period. This is in agreement with the character of the lowland pollen assemblages at Alpiarça, which indicate a stage of open water. *Pinus* has probably been an important member of the upland vegetation.

zone B

Strong degeneration of the *Pinus* vegetation and degeneration of the *Quercus* vegetation. Development of the maquis; first low maquis, later-on high maquis.

zone C

The changes in the pollen assemblages may indicate a more or less rapid and severe change in the vegetation, such as is known from periods of the Bronze and Iron Age.
The subzone with high *Erica scoparia* pollen values (and low *Rumex acetosella* and *Anthemis* pollen values) may indicate a regeneration of the maquis-vegetation. Subzones with high pollen values of *Rumex acetosella* and *Anthemis* type may indicate periods of strong human activity. As a result of human influence, *Pinus* forests disappeared and vegetation with *Quercus* trees diminished and were replaced with maquis and open vegetation.

zone D

The presence of *Ulmus* and *Castanea* pollen and the high pollen values of *Olea* point to an age of ca. 2000 BP (Roman Aera).
Pinus must have been completely absent in the surrounding vegetation. The maquis vegetation seems to have been partly replaced in part by a *Sambucus nigra* vegetation. The extraordinary high percentage of *Sambucus* might however be the extralocal effect of nearby stands along the slopes of the castro.

B. Pollen zones in lowland pollen diagram

zone LA

The pollen assemblage indicate a stage of open water.

zone LB

The presence of alder carr seems likely because of the presence of *Osmunda* spores and high values of *Alnus* and *Dryopteris* pollen and spores.

zone LC

More open alder carr with *Vitis*.

zone LD

Alternation of alder carr with *Myrica* carr with *Lythrum* and *Frangula*.

zone LE

Alder carr with *Hedera* and *Vitis*.

zone LF

Alder carr without much *Dryopteris* in the understorey.

SERRA DA ESTRELA

Saturday 25 May		**arrival in the Serra da Estrela**
17.00		arrival in Centro de Acolhimento in Penhas Douradas (above Manteigas)
19.00		dinner in Caverna do Viriato, Penhas Douradas
21.00		evening lecture and poster session in Centro de Acolhimento
Sunday 26 May		**Degradation stages of vegetation**
08.00		breakfast in Caverna do Viriato
08.30 - 09.15		drive to *Taxus* vegetation
09.15 - 09.45	Stop 1	study of *Taxus* ecology, *Betula* and rye fields
09.45 - 10.10	Stop 2	view over Zêzere valley
10.15 - 12.00	Stop 3	degradation stages of terrestrial vegetation at 1600 m altitude
12.00 - 13.00		lunch in the field (or cars)
	Stop 4	photo stops on the way to ...
13.00 - 14.00	Stop 5	drive to Torre, summit of Estrela
14.00 - 16.00	Stop 6	vegetation above 1800 m: peat mires; degradation of vegetation
16.00 - 17.00		return to Centro de Acolhimento by way of Sabugueiro
19.00		dinner in Caverna do Viriato
21.00		evening lecture and poster session in Centro de Acolhimento
Monday 27 May		**Forest limit; lake and mire succession**
08.00		breakfast in Caverna do Viriato
08.30 - 09.30		drive to summit
09.30 - 12.00	Stop 7	walk to sites around forest limit and panoramic view over lower sites
12.00 - 13.00		lunch, anywhere (field, cars)
13.00 - 13.30		drive to Lagoa Comprida
13.30 - 16.30	Stop 8	walk to sites 1650 - 1750 m altitude; lake and mire succession
19.00		dinner in Caverna do Viriato
21.00		evening lecture and poster session in Centro de Acolhimento
Tuesday 28 May		**Walk to Casal do Rei, "medieval" village**
08.00		breakfast in Caverna do Viriato
08.30 - 10.00		drive to Cabeça on W side of Serra da Estrela
10.00 - 16.00		walk to Casal do Rei; patches of primeval laurosylvan vegetation, land-use patterns, etc.
16.00		return to Centro de Acolhemento
19.00		dinner in Caverna do Viriato
21.00		evening lecture and poster session in Centro de Acolhimento
Wednesday 29 May		**Candeeira valley**
08.00		breakfast in Caverna do Viriato
08.45 - 09.30		drive to Covão da Metade
09.30 - 15.00		walk to Candeeira and Lagoa dos Cântaros; swimming party in Lagoa (towel!)
15.00		return to Centro de Acolhemento; discussions on standard diagram
18.30 - 19.00		drive to ...
19.30		final dinner in Seia
Thursday 30 May		**return**
very early		day-long drive to Aeroporto of Lisboa; no time for breakfast!

INTRODUCTION

by C.R.J.

A little bit of palynological and ecological phylosophy

Why is it that the dutch palynologists from Utrecht study past and present vegetation in a variety of landscapes in southern direction outside their own country? Several explanations are and have been suggested:

It is said that flatlanders are naturally attracted to areas where things are less horizontal. Could be ... Others have suggested that The Netherlands is a small country with too many pollen pickers. Some suggest that because the sun is brighter in the south than in the north, northerly people are attracted to the south, and that we compensate there for the lack of horizontal flat terrain by taking a horizontal position in worship of the sun. Again others have accused us that we are not really grown-ups, because they observe an element of boy-scouting in our work. Well, you never know for any individual to what extent some of these explanations are true. However, the real (i.e., official) reason is more prosaic:

In reconstructing the development of vegetation in a large area for the purpose of understanding the complex pattern of environmental parametres and processes that are the underlying cause for specific developments, (Do you still follow me?) two main approaches come into consideration:

A. From a network of sites across a large area (Europe), isopol or isochrone maps may be constructed that describe patterns on that scale. For these maps often a rather low resolution in pollen types is used, mainly the wind-blown dominant pollen types that characterise vegetation at the level of plant formation. The advantage of this approach is that the data can easily be stored and processed in a rigorous and quick way. Disadvantages are that such data give only rarely insight in the complex patterns and processes on a regional and local scale, because: (1) The value of rare pollen types as indicators is underestimated; (2) The palynological sites are often too far apart for the study of the pollen-dispersal characteristics of the various pollen types; and as a consequence (3) The chronology of the pollen assemblages can not accurately be derived from pollen itself. These disadvantages are less strong in flat country. But in the mountains, this approach is less useful due to the large diversity in plant cover and environment over short distances.

B. From a detailed study of the pollen pattern in time and space in a small segment of a mountain range, the fine-scale mosaic of vegetation can be reconstructed in relation with local site factors such as soils, climate and flora. Advantages over the other approach are: (1) The presence of ecotones close together (i.c., altitudinal zonation) results often in pollen diagrams with fluctuations in the pollen curves that are related with the passing of vegetation boundaries over the site; (2) Changes in vegetation in one area are reflected in adjacent areas because of pollen transport, a phenomenon which can be used for the establishment of a chronology based on trends in pollen curves; (3) Differences in sizes of the basins studied palynologically and in character of basin-infill (e.g. peat, lake sediments) contribute to an understanding of the patterns and processes on the scale of single valleys; and therefore (4) The pollen assemblages can be interpreted in terms of local site conditions, geomorphology and human occupation.

The consequence of the fine scale of such studies is that the investigations are done in an area of restricted size, in the magnitude of 25 to 50 square kms or along transects up to 100 km long but considerably narrower. The results then apply only to these small-sized areas. This is a disadvantage for correlation with the global studies of oceanographers and climatologists.

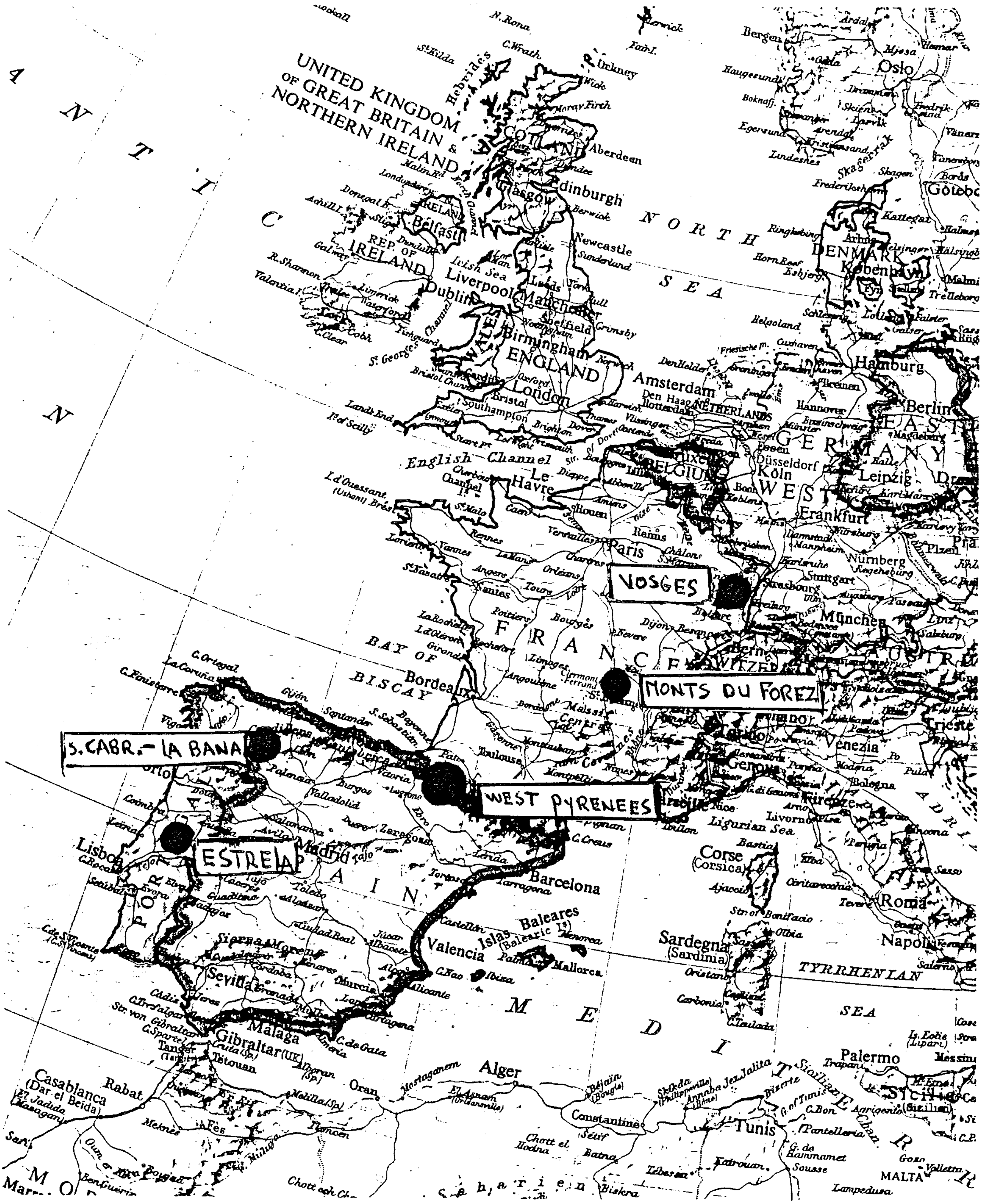
Middle-High Mountain Project

A. General approach

Fine-scale palaeo-ecological studies are as a matter of fact very time-consuming and the study of sites situated in a grid fine enough to satisfy our scientific goals is beyond the means of any institute. The fine-scaled studies in a mountain range are therefore carried out along transects rather than in a grid. Also a very restricted number of mountain ranges can be studied, which then have to function as type-mountains. The type-mountains should contrast each other, in order to be able to study a diversity of patterns in time and space. The criteria for the selection of type-mountains were that these mountains must show strong differences in macro-climate, vegetation and flora, because these features are important parametres in defining the nature of competition (or interaction) between plant species. In the selection of the type-mountains, the soil factor was kept uniform as much as possible. Therefore, mountains were selected with granitic parent material. The reason for the choice of granite (rather than, e.g., limestone) is for practical reasons: granite is relatively impermeable for water and the number of sites available for study is as a consequence relatively high. A criterium in the selection of type-mountains is also that they should have a sufficient number of contrasting sites in the various altitudinal vegetation belts. The ideal situation would be to have soils and large- and small-sized mires and lakes in every vegetation belt. This dream has never come true (like any dream), but an attempt was made in all selected type-mountains to approach the ideal situation. From all these considerations it follows that the selection of type-mountains was no easy matter; considerable energy, often to be measured in years, was used to survey potential mountain ranges. An account of these surveys is interesting in itself and would often take anecdotical form, but there is no place for it in this guide-book. Many people have participated in these surveying parties, e.g. most of the Dutch present at this excursion, contributing considerably to the selection of regions with their intimate knowledge of plants, animals and not to forget Man, or otherwise with their enthousiasm and inexhaustable energy (which can be tiring, especially at night).

B. Development of the Middle-High Mountain Project

(1) The Project began in 1970 in the Vosges mountains (Vogesen) in north-eastern France. The Vosges have an altitudinal zonation of (a) a colline zone of deciduous forests, (b) a montane zone with mixed forests of *Abies alba* and *Fagus sylvatica*, (c) a lower sub-alpine zone with *Fagus* krummholz forming the forest limit and (d) an upper sub-alpine zone without trees.
In 1974, a large survey was carried out from The Netherlands in south-western direction. Four additional type-mountains were selected in that year and in the following years:
(2) Monts du Forez, north-east part of Massif Central somewhere in the middle of France. It has a montane vegetation zone like the Vosges with *Abies alba* and *Fagus sylvatica*; *Fagus* is at the tree limit. Climate, however, is more continental than in the Vosges and dimensions of vegetation zones are different.
(3) Western Pyrenees, France, near the western limit of *Abies alba*. We abandonned this area after a few surveys, for obscure reasons (e.g., lack of man-power).
(4) Western Cantabria, north-west Spain. The montane zone has *Quercus pyrenaica* and *Fagus sylvatica*; the latter is at the tree-limit. Climate is oceanic. It was difficult to find a suitable type-mountain near the western limit of *Fagus*. An area near the village of La Baña in the Sierra de Cabrera Baja was finally selected, just outside the range of *Fagus*. This type-mountain is situated at the lee-side of a larger mountain complex; climate is therefore a bit continental to our taste, but not too much. The flora is however western-European in outlook with *Corylus avellana* up to the tree-limit. Also parent-material is not granite but schists, which is (we think) for plant-growth not too different. But anyway, the mountain is well-suited for palaeo-ecological studies having a range of good sites in the various altitudinal vegetation belts.


VOSGES
MONTS DU FOREZ
S.CABR. - LA BANA
WEST PYRENEES
ESTRELA
UNITED KINGDOM OF GREAT BRITAIN & NORTHERN IRELAND
REP. OF IRELAND
ENGLAND
WALES
NORTH SEA
English Channel
BAY OF BISCAY
FRANCE
SPAIN
PORTUGAL
NETHERLANDS
BELGIUM
DENMARK
GERMANY
Oslo
Bergen
Göteborg
Aberdeen
Edinburgh
Glasgow
Belfast
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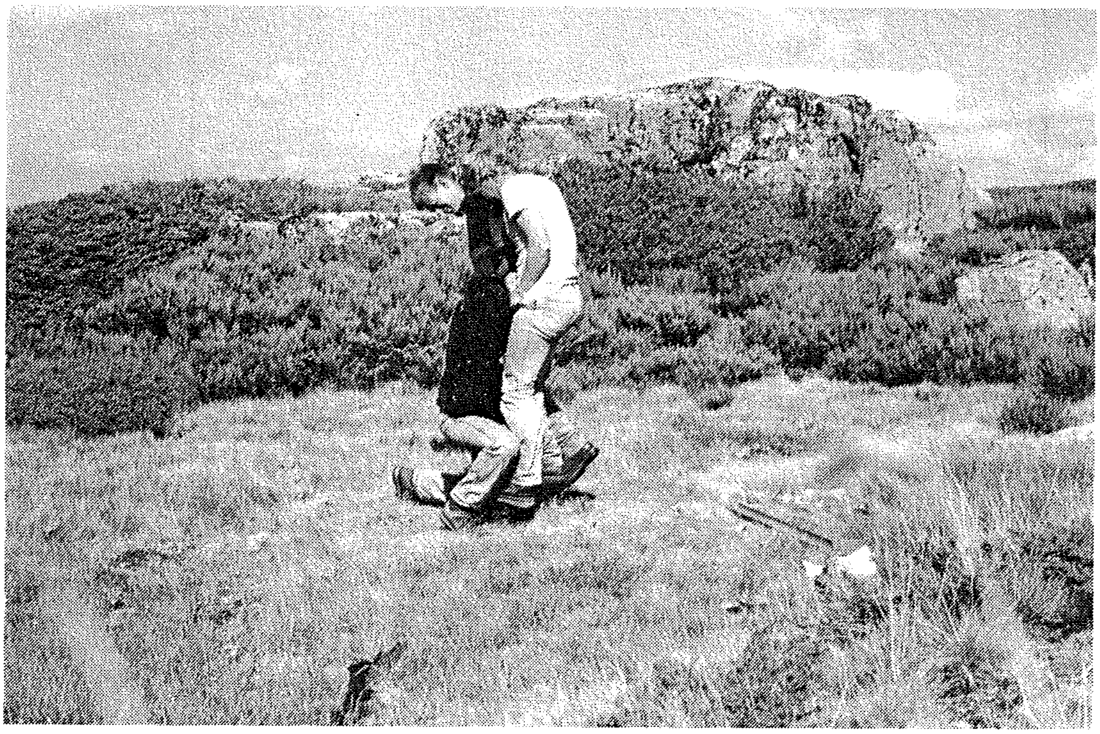
Hamburg
Berlin
Leipzig
Köln
Düsseldorf
Frankfurt
Nürnberg
Stuttgart
Strasbourg
München
Paris
Le Havre
Rouen
Reims
Nantes
Bordeaux
Toulouse
Marseille
Nice
Genova
Venezia
Firenze
Livorno
Roma
Napoli
Trieste
Barcelona
Valencia
Madrid
Lisboa
Sevilla
Malaga
Gibraltar
Zaragoza
Baleares
Mallorca
Corse (Corsica)
Sardegna (Sardinia)
Palermo
Alger
Oran
Tunis
Rabat
Casablanca (Dar el Beida)
TYRRHENIAN SEA
Ligurian Sea
MALTA

(5) Serra da Estrela, central-east Portugal. The montane vegetation zone has neither *Fagus* nor *Abies*, nor *Corylus*, but *Quercus pyrenaica*, which is (or rather, was) also at the tree-limit. Compared to the other type-mountains, climate has Mediterranean characteristics, but Atlantic and Continental climatic features are pronounced too.

By studying and comparing in detail the present-day and past distributions of plant species in these type-mountains, we hope(d) that something can be said about the reasons for the observed developments. Is it a matter of migration? or rather competition/interaction between different (sets of) plant species? or is climate the Big Brother controlling all? To take an example: *Corylus* was in the Vosges and in the Forez in the early and middle Holocene very abundant in the upper montane zone, but in the Serra da Estrela it was and still is absent; Why??

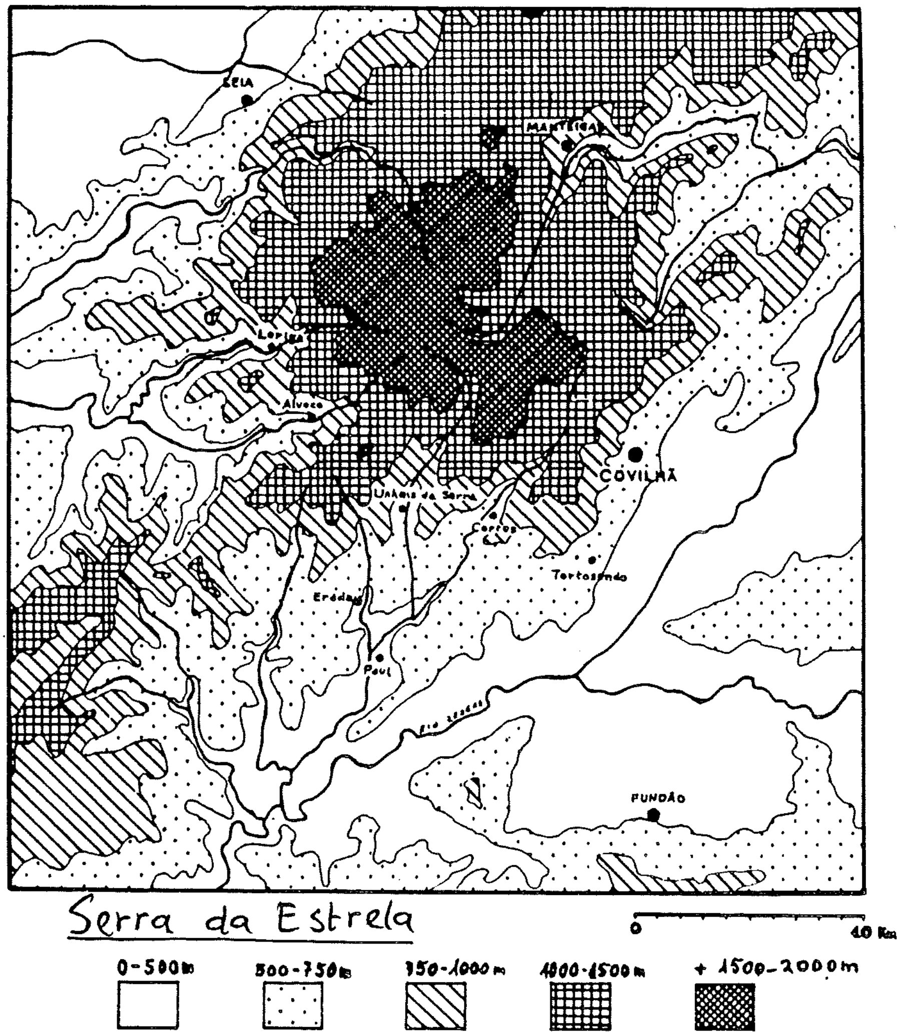
At the present time it seems very unlikely that all the envisaged sub-projects (study of the different type-mountains) will be completed. Most of the work in the Vosges is done, whereas in the Serra da Estrela and in the Monts du Forez it is half-way completion. The work in La Baña is still in its initial phase and may not be completed within the framework of the Middle-High Mountain Project. Anyway, *quoi qu'il soit*, after having shown (some of) you around in the Monts du Forez in 1984 and in the Vosges in 1989 it is fine to have you now in this fantastic fairy-land of the Serra da Estrela.

Welcome to the land where Thor built a few Tors on the Torre!

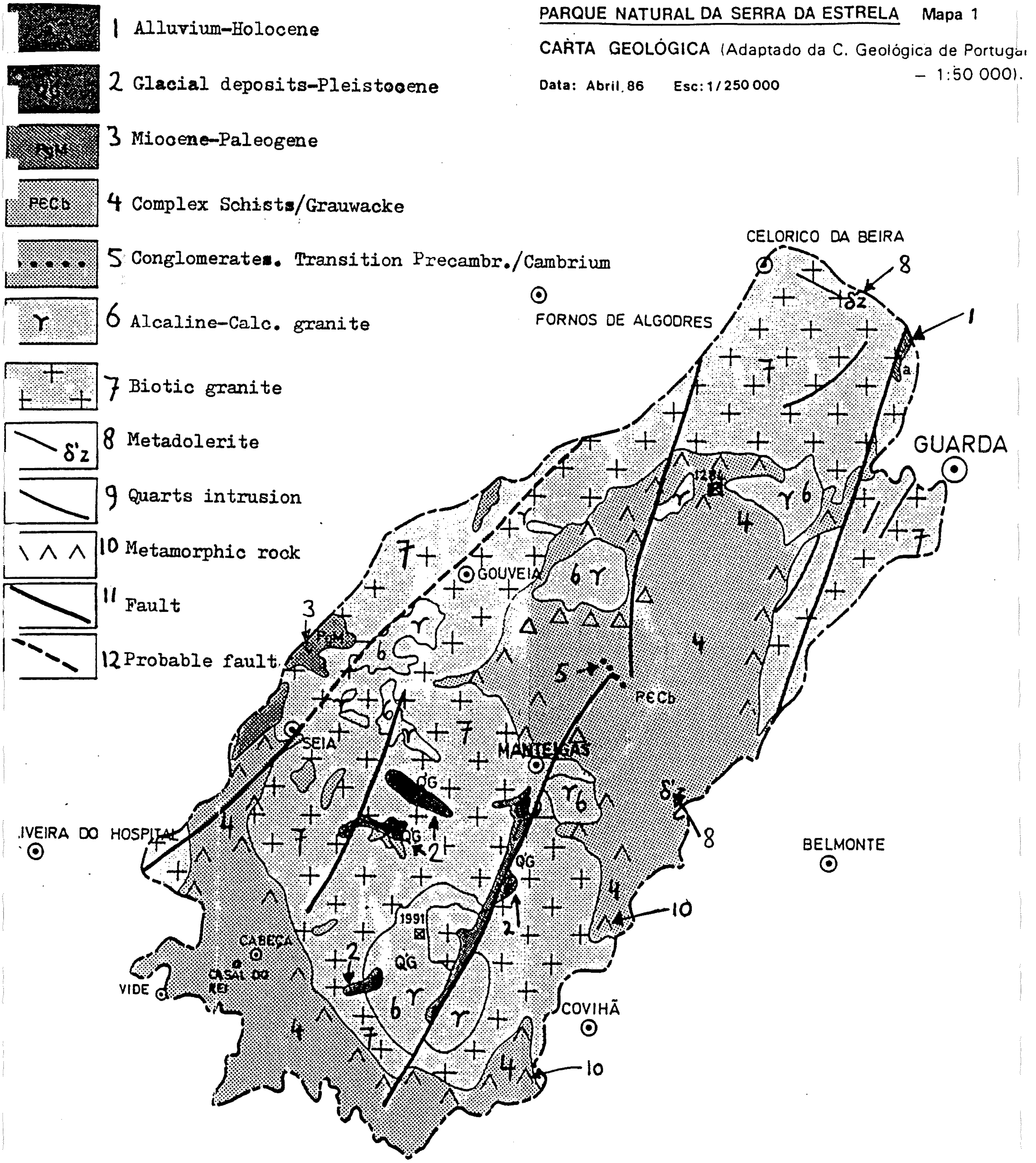


GEOLOGY

The central part of the Iberian Peninsula is formed by the Meseta or Spanish high-plain. A row of predominantly granitic mountains, the Central Iberian Cordillera, runs east-west through Iberia, over the Meseta and beyond. The westernmost part of this Cordillera is formed by the Portuguese mountains of Serra da Estrela and Serra da Gardunha (lying south of the Estrela). The Serra da Estrela has been formed in the hercynic orogenic phase and is built up in its central part of granitic rock of Palaeozoic age, in its periphery of Cambrian and Silurian schists. The mountain range is southwest - northeast orientated and is steep on all sides. The south and west sides are steepest and have short but deep incisions. The northeast side has longer incisions, resulting in long, northeast-running mountain ridges, separated by the valleys of Rio Mondego, Rio Zêzere and Rio de Beijames. If we look the map showing gross altitudinal categories, then the plateau-like character of the area over 1000 m altitude is evident. Especially the area over 1500 m is rather flat and when driving over this high plain we can look beyond the steeper slopes at the margin of the massif down to the populated and often damp areas at much lower altitudes. The highest summit (Torre, alt. 1992 m) is dome-shaped comparable with a "Ballon" in the Vosges mountains or a "Belchen" in the Black Forest.



Serra da Estrela


PARQUE NATURAL DA SERRA DA ESTRELA Mapa 1
CARTA GEOLÓGICA (Adaptado da C. Geológica de Portugal – 1:50 000).
Data: Abril.86 Esc: 1/250 000
1 Alluvium-Holocene
2 Glacial deposits-Pleistocene
3 Miocene-Paleogene
4 Complex Schists/Grauwacke
5 Conglomerates. Transition Precambr./Cambrium
6 Alcaline-Calc. granite
7 Biotic granite
8 Metadolerite
9 Quarts intrusion
10 Metamorphic rock
11 Fault
12 Probable fault
PGM
PЄCb
δ'z
QG
CELORICO DA BEIRA
FORNOS DE ALGODRES
GUARDA
GOUVEIA
SEIA
MANTEIGAS
BELMONTE
COVIHÃ
CABEÇA
CASAL DO REI
VIDE
1991

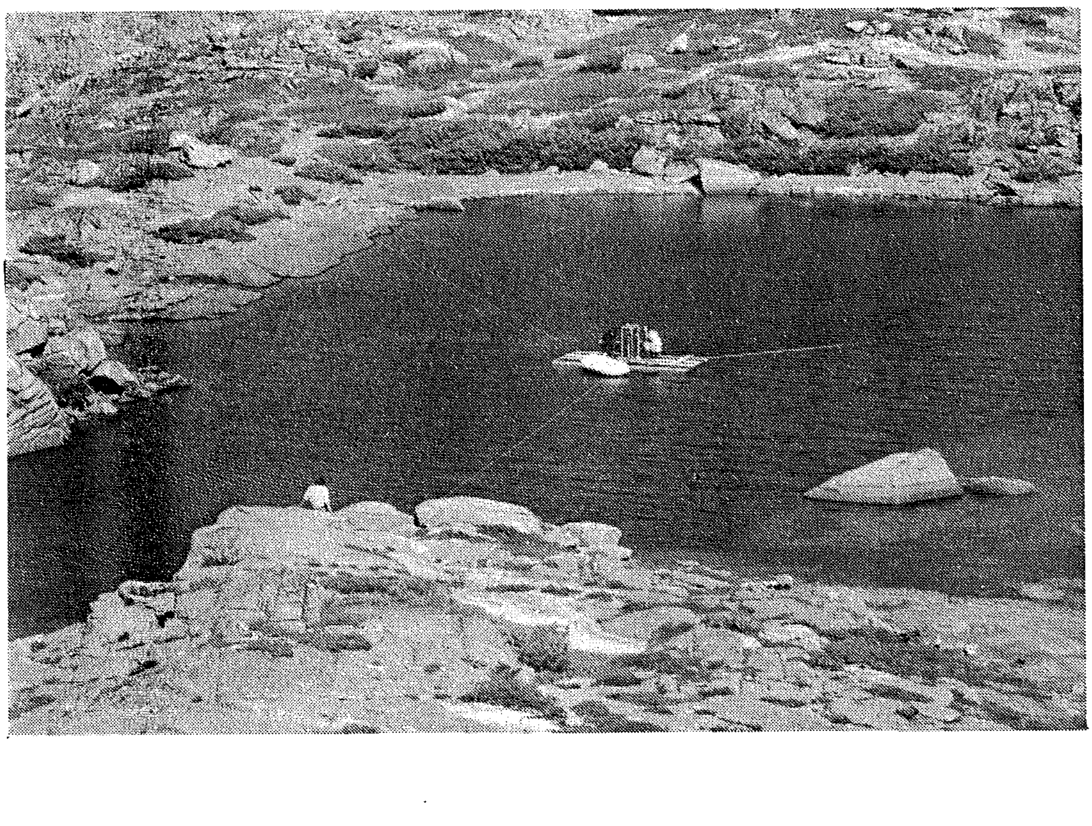
GEOMORPHOLOGY

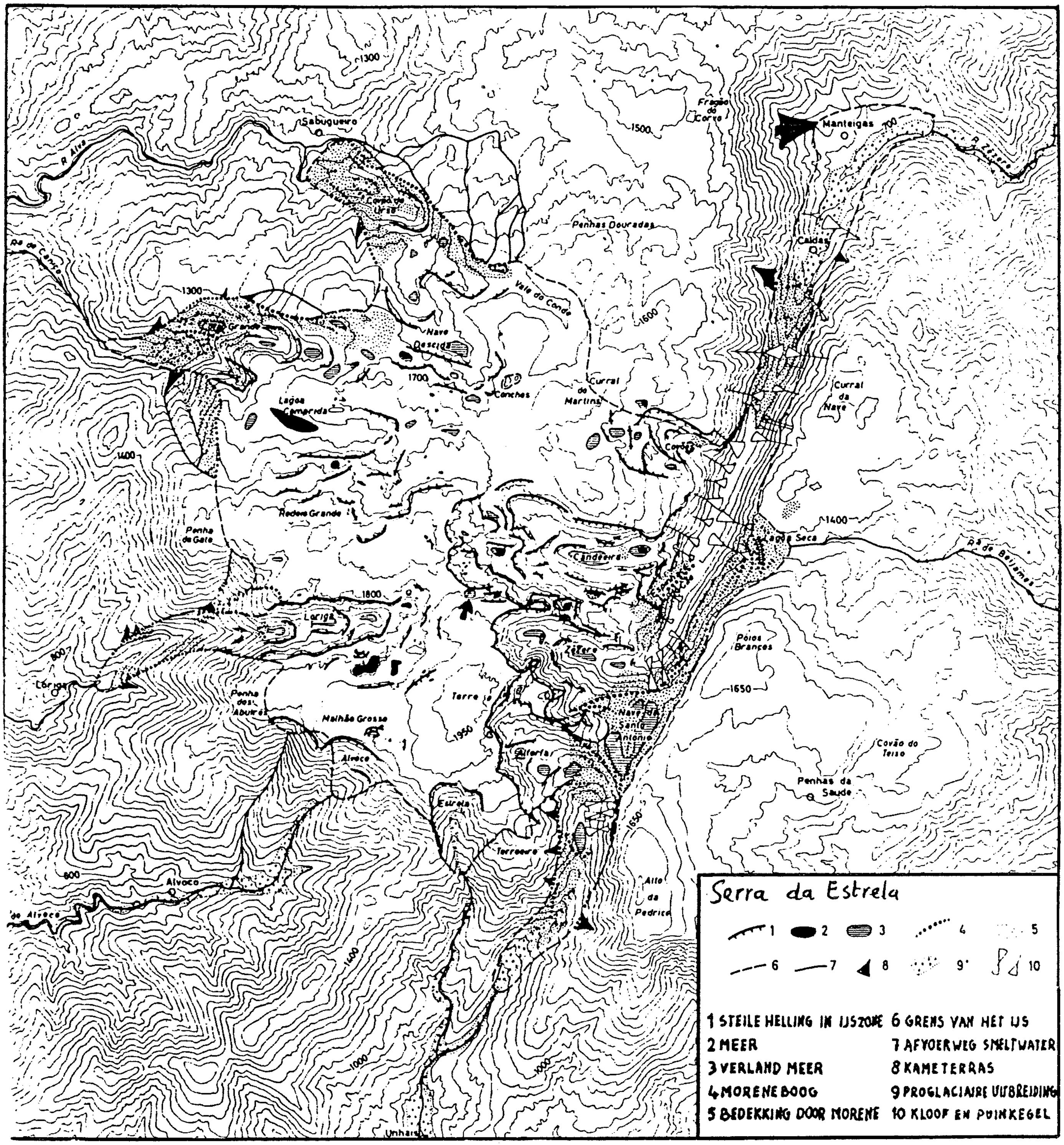
The Serra da Estrela with its altitude of 1992 m is one of the very few mountains in Portugal having had glaciers during the last glaciation. All major geomorphological structures are glacial, or at lower altitudes periglacial. The glacial geomorphology was studied by S. Daveau (1971) (Fig. *). Witnesses of glaciers include cirques (many now occupied by lakes), glacial escarpments, U-shaped valleys, suspended valleys with associated waterfalls, morainic arcs, kame terraces, polished rocks, "roches moutonnées" and tills. The glacier type was that of a plateau glacier from which a number of glacier tongues descending like a star (estrela = star) in all directions, but mainly to the north-east. About 70 km² was covered by ice. By far the longest tongue was a glacier towards the north-east flowing into what is now the valley of Rio Zêzere south of Manteigas. This glacier had a number of tributaries from the north-west; the tributary valleys are now suspended valleys. We can estimate the former thickness of the glacier in the Zêzere valley by looking at the altitudes of the mouths of the suspended valleys, high above the floor of the Zêzere valley. The most important tributary came from the Vale da Candeeira, which has its own system of glacial features. The period of snow-melt (April-May) is the most impressive time when the rivers and streams have a maximum load of water and the sound of falling water can be heard everywhere in the Zêzere valley.

Many very steep glacier cirques are present in the central part of the Serra da Estrela, like Lagoa Redonda, Lagoa dos Cântaros, Covão Cimeiro (*or* Covão da Cima; informally called Ulmus-mire because of its surface patterns), Covão do Boieiro, Covão da Metade, cirque of Lagoa do Peixão.

An interesting feature is the intermontane basin of Nave de Santo António at 1550 m altitude. It may be visualised perhaps that this basin was free of ice at some stage during the Weichselian, and that firn basins and associated glaciers were only present in southwestern and northeastern direction. If this is true, then the Nave de Santo António should contain very ancient deposits indeed. However, a thorough survey for superficial peat layers and a pollen diagram of the deepest organic deposit (75 cm only) have not confirmed this. So it seems wise to abandon this visualisation - but please give your opinion when we are at the site.

Periglacial features for cold climates in granitic regions are as usual Tors. These impressive structures are present abundantly, contributing to the bouldery aspect of the Serra da Estrela. And last but not least, recent geomorphological structures are strongly influenced by human-induced erosion.



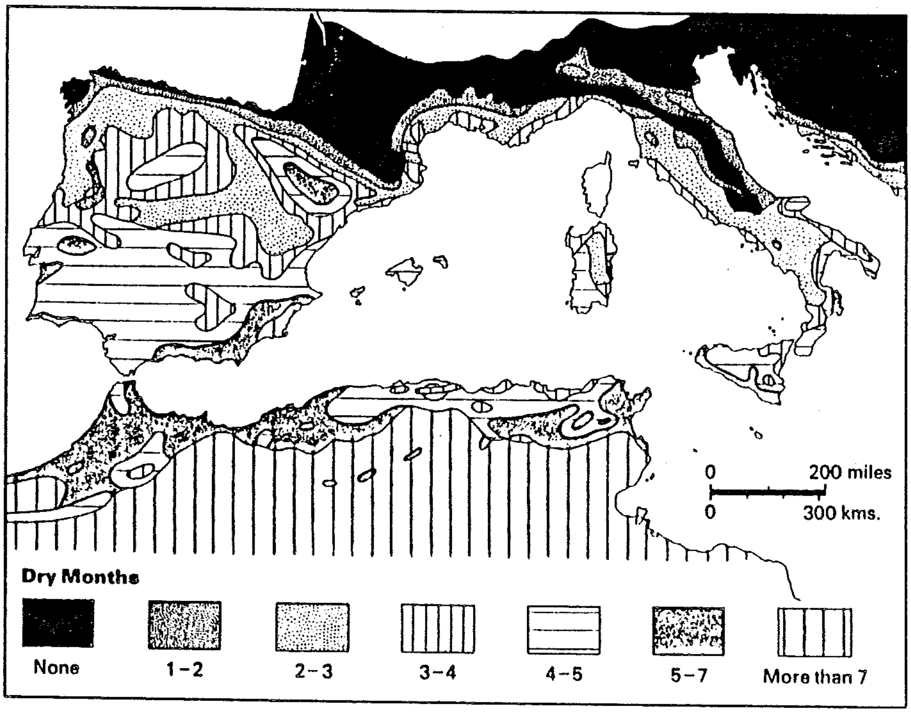


1. steep slope in glaciated area
2. lake
3. filled-in lake
4. morainic arc
5. terrain covered with moraines
6. limit of ice-cover
7. drainage of meltwater
8. kame-terrace
9. proglacial debris
10. talus cone

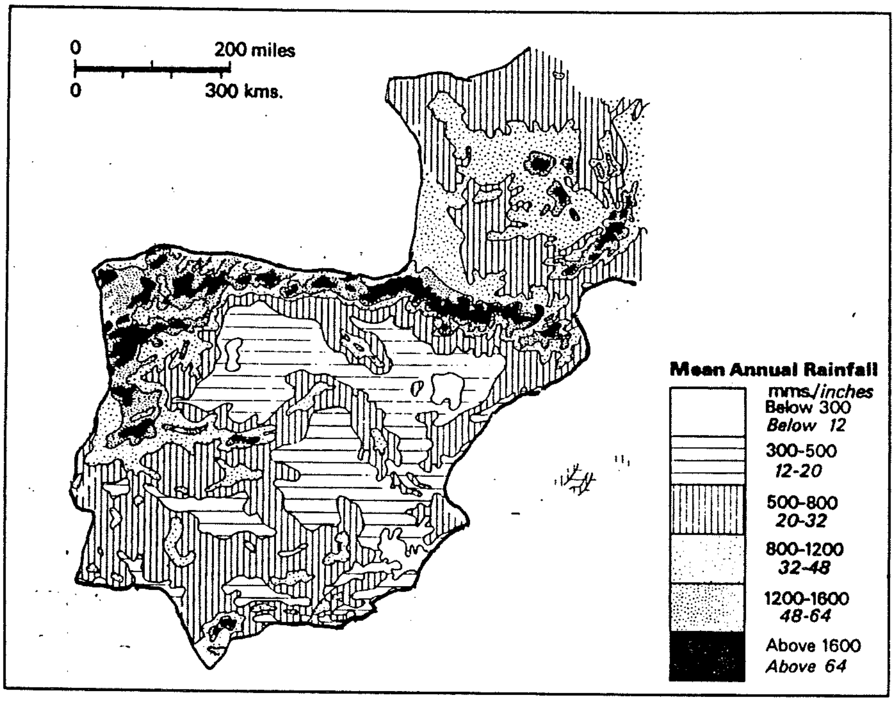
CLIMATE

The famous 1881 scientific expedition to the Serra da Estrela organized by the "Sociedade de Geografia de Lisboa" led to the establishment of the meteriological station of Penhas Douradas (above Manteigas) in 1882 at an altitude of 1380 m. From that date on there is a record of the regional weather conditions in the Serra da Estrela. The climate has been characterized as "subtropical-maritime". There are large climatic differences between mountain sides and between altitudes. The data below are averages from one locality and actual rainfall and temperature may differ even at neighbouring localities. Annual precipitation differs strongly between years, but at Penhas Douradas it is as a mean ca. 3000 mm. A striking feature in the cirques (covão = cirque) is the "mountain wind" during sunny days with stable weather. The wind blows upslope in the morning and clouds often appear above the plateau in the afternoon. With decreasing temperatures in the evening the cold air masses sink down into the cirques, the skies clear and bugs and mosquitos of various sizes have a short period of high activity, it seems especially on camp sites. The summers in the Serra da Estrela are generally dry, but the weather in May can be anything. Most of the precipitation falls between October and May and these months also have most of the days with fog (120 out of 145 per year). Snow falls every year above 750-800 m altitude. Penhas Douradas has 34 days with snowfall and 44 days with snow cover per year. The summits have of course much more than that: over two months of snow per year, and above 1700 m altitude it can accumulate up to 5 m in thickness (presumably in the cirques).

Weather is usually windy; especially precipitation is often accompanied with very strong winds. Mean annual temperature at Penhas Douradas is 8.9 °C; January is the coldest month with 2.4 °C, May has 9.2 °C and July, the warmest month has 17.2 °C. The mean annual sunshine is 2650 hours with a minimum of 121 hours in January and a maximum of 375 hours in July.

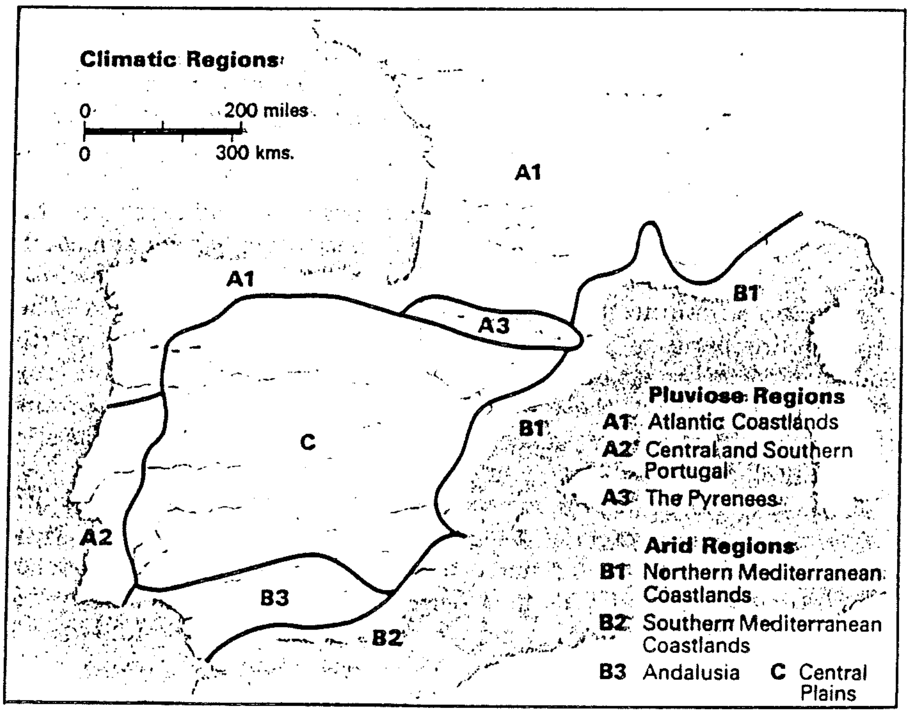


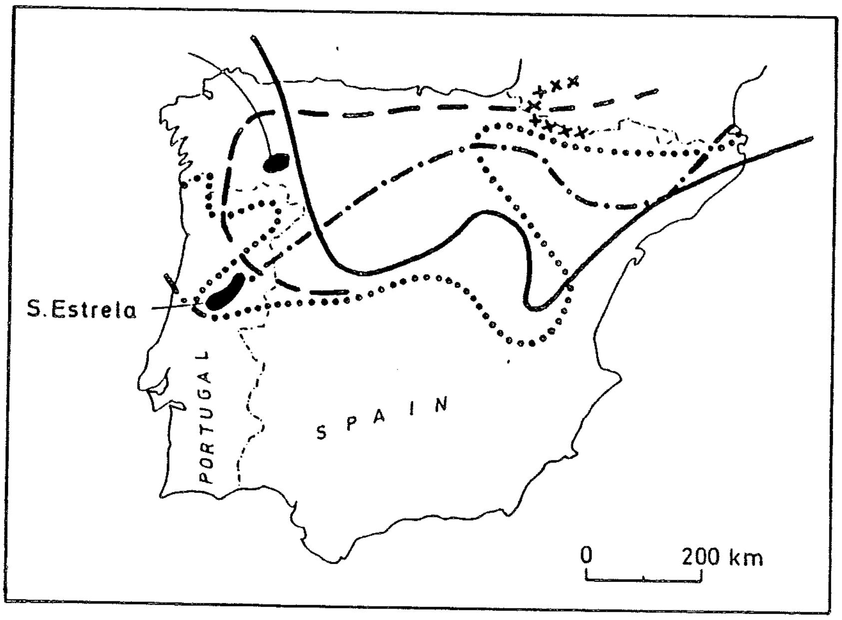
Dry month = PJ/T < 10; where P = monthly precipitation in mm, J = number of rain-days, T = mean monthly temperature (Birot, 'Sur une nouvelle fonction d'aridité en Portugal', *Ann. Fac. Sciences*, Oporto, xxx, 1945, pp. 90–101).



Position in the Iberian peninsula

The Serra da Estrela lies on the meeting ground of three climatic regions: the Atlantic region to the north and west, the Mediterranean region to the south and the Continental region to the east. The critical location between these domains is reflected in the conjunction of boundaries of the areas of a number of important tree species: the Serra da Estrela lies at the northern limit of *Olea europaea* and *Quercus coccifera* and near the southern limit of *Pinus sylvestris*. In fact, the Serra da Estrela was chosen for study because of this gross ecotonal (ecoclinal?) location near climatic boundaries. The response of vegetation to even small changes in the macro-climate would be quicker and more apparent in this situation than in the centre of large climatic regions. Another attractive reason for palaeo-ecological work in the Serra da Estrela is its connection with changes in the ocean circulation off the coast of Portugal. Especially the change from Late-Glacial to Holocene, when cold sea-water (or even sea-ice) was replaced by warmer surface water, would trigger changes in the vegetation on the mainland.





——— southern boundary of *Fagus sylvatica*
◦ ◦ ◦ ◦ ◦ northern boundary of *Olea europaea*
—·—· northern boundary of *Quercus coccifera*
— — — western and northern boundary of *Pinus sylvestris*
× × × × western boundary of *Abies alba*

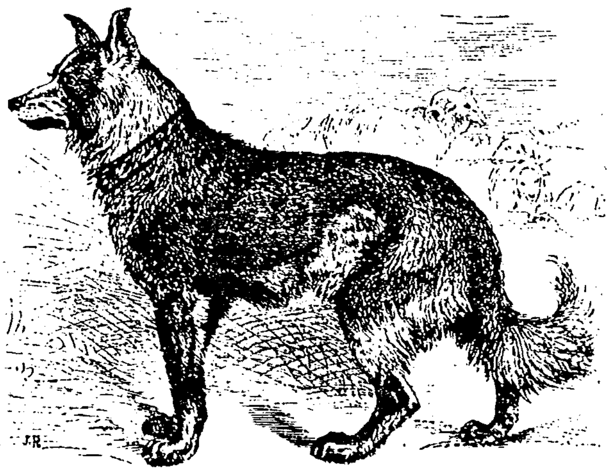
LAND USE

Grazing

In the Serra da Estrela the herds include sheep and goats, but rarely cows. The effects of grazing differs between animal species, due to differences in diets. Goats eat everything, but they are reported to prefer *Cytisus* and *Chamaespartium lusitanicum* (the tougher stuff). Sheep prefer grasses, herbs and *Calluna*. The total number of grazers in the Serra da Estrela was 29,321 animals in 1978. The following table gives an impression of the numbers in the communities participating in the high plateau:

	sheep	goats	shepherds	
Covilhã	1511	4714	136	
Gouveia		4174	949	83
Manteigas	920	1080	32	
Seia	5745	1829	244	

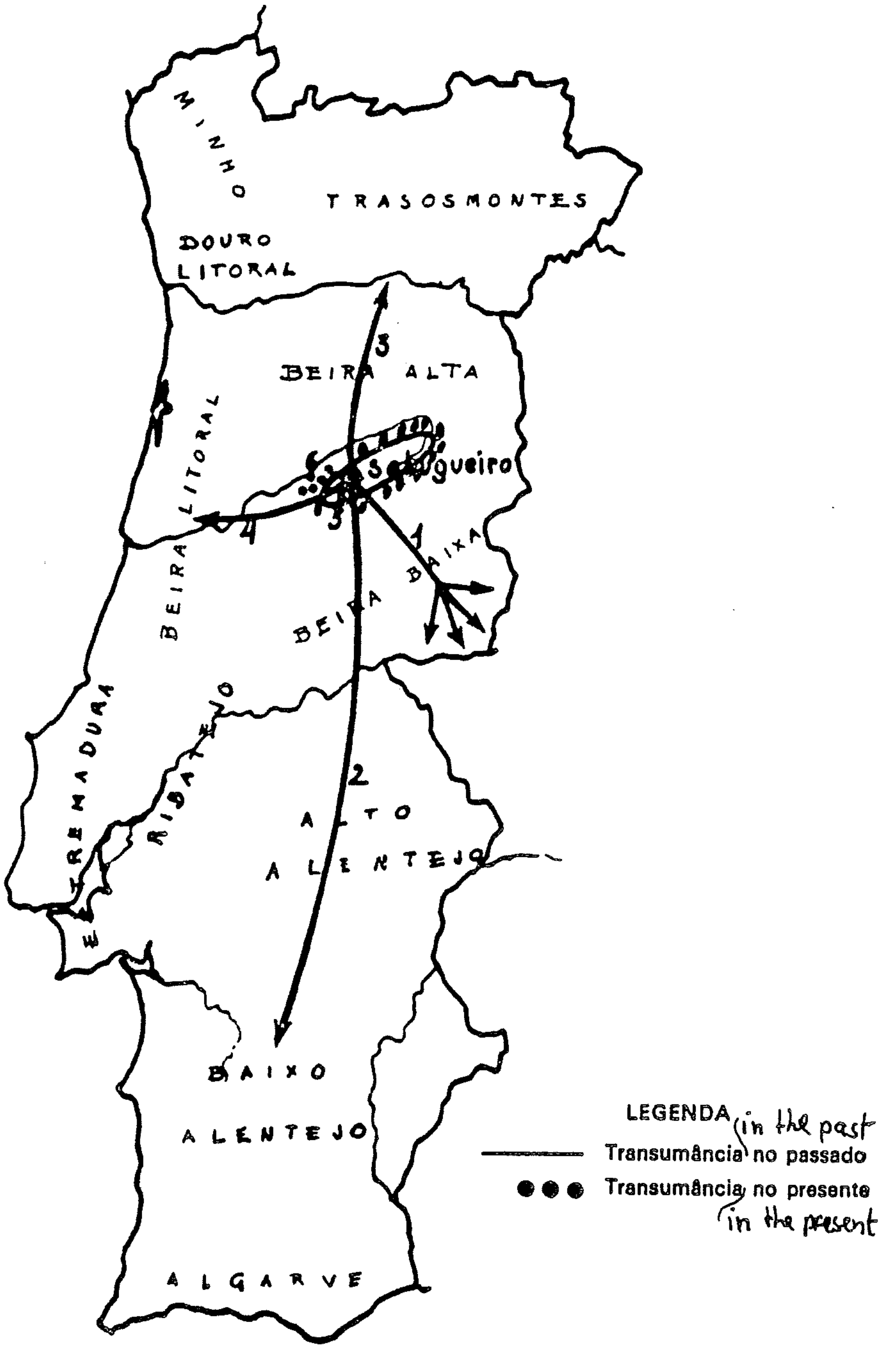
As you can see, the profession of shepherd is something to be proud of. In the past, flocks of sheep and goats travelled over long distances to and from the Serra da Estrela, the so-called Transhumance. Today, however, the movements of animals are restricted to traveling from low altitudes to the mountains in spring and the reverse during fall. There is also trekking of flocks over very short distances within a day: to the plateau in the morning and down into nearby valleys in the evening. We might be able to observe an example of the latter, if we meet a flock in the Candeeira, coming from the Zêzere valley each day. The night is spent by shepherds and animals alike, especially during bad weather, in old-fashioned "krals". If you use your eyes, you will see several on our trips.



Fires

All over Iberia, fire is the tool to create grasslands suitable for grazing. The Serra da Estrela is no exception. One observes almost everywhere the blackened slopes testifying to the use of fires to keep down the growth of trees and nasty bushes and to trigger the growth of grasses. Fires are deliberately ignited after the dry summer period when forests and shrublands are most susceptible, usually in September. During clear autumn nights, the entire mountain range when seen from a distance can appear to be on fire. The result of burning is in the long run, but often also in the short run, a tremendous erosion of organic soils or even sands, leaving bare stones without growth of vascular plants. Erosion is greatly enhanced by modern forestry, i.c. the plantation of *Pinus* and *Eucalyptus*. Tree plantation is preceded by mechanical destruction of the original local shrub vegetation and deep-ploughing of the soils, which in itself invites erosion. The plantations are extremely susceptible to ignition, much more so then the original vegetations. The fires are also much hotter, so that also the roots of the last remaining perennial herbs and shrubs are killed. Regrowth of spontaneous vegetation is therefore very slow and erosion processes have time to play their games.

TRANSUMÂNCIA NO PASSADO E NO PRESENTE DO «GADO» DA SERRA



THE FIRST ASCEND

Stop 1

Taxus

Natural occurrences of *Taxus* in Portugal are found only in the mountains in the north of the country. The present-day occurrences in the Serra da Estrela are (1) at this site, in the upper Zêzere valley (less than 20 trees between 1300 m and 1370 m altitude in the north-exposed moist gully of Ribeira da Barroqueira), (2) according to Batista (1982): one tree above the Candeeira valley, 2 km to the north of this site (1600 m altitude, moist south-exposed slope), (3) according to Pinto da Silva & Teles (1980): several trees on the sands of Ribeira do Teixo (= *Taxus* rivulet) and trees or shrubs at several other localities. Pinto da Silva & Teles mention historical records from the last century up to 1750 m altitude. Toponyms indicate former occurrences of *Taxus* at several additional sites: Teixeiras, Covão do Teixo (4 km to the east, 1500 m altitude), Teixoso (a village 10 km to the east).

Palynological records of *Taxus*
The Candeeira diagram (1 km to the north, 1400 m alt.) records the former occurrence of *Taxus* from Zone B2b (ca. 9550 BP) to Zone D3a (ca. 4950 BP). Above this level, no *Taxus* grains were found - despite the present-day occurrence of *Taxus* trees both one km to the north (one tree) and one km to the south (this site). The lack of pollen underlines the very minor role of the species in the surroundings in the last ca. 4950 years.
The Lagoa Comprida 2 diagram (1645 m alt.) shows a frequently interrupted *Taxus* curve throughout the recorded period (the last 12000 years, with a possible hiatus between 10200 and ca. 9000 BP); there are increases in the values at ca. 8000 BP (dating by correlation of pollen curves with Candeeira diagram) and at ca. 5000 BP, and a decrease at ca. 2000 BP. However, we did not check the reliability of the identifications of the grains in the upper part of the diagram; *Taxus* is a difficult and spore-like grain.
The Lagoacho das Favas diagram (1645 m alt., 50 m distance from Lagoa Comprida 2) shows scattered *Taxus* grains from the base (ca. 7000 BP) to ca. 4100 BP, but not later. Pollen identifications seem to us to be reliable. The contrasting *Taxus* behaviour between Lagoacho das Faves and Lagoa Comprida 2 (if the pollen identifications are accepted) suggests that the pollen encountered is derived from only few trees standing very near to the sites (extra-local pollen deposition).
The diagrams from higher altitudes show little or no *Taxus* grains (Charca dos Cões, 1795 m alt.; Lagoa das Salgadeiras, 1835 m alt.; Lagoa Clareza 1, 1855 m alt.). In Charca dos Cões and Lagoa Clareza 1 the type has possibly been overlooked (but I think it is very scarce), but probably not so in Lagoa das Salgadeiras. It is thought that we are here above the *Taxus* limit, because of this pollen scarcity, the present-day distribution of trees, historical records and toponyms.
The cause for the *Taxus* decline at different moments at different sites is open for discussion. I think it could be human influence, but please think about it.

Betula

It is convenient to draw your attention here to the present-day distribution, ecology and history of *Betula* and to start a discussion.
Present-day distribution. I think that these moist gullies in the upper Zêzere valley are amongst the very few sites where *Betula* has had a continuous foothold during most of the Holocene (the last 10000 years). Pinto da Silva & Teles (1980, p. 29) give a photograph of an apparently natural *Betula* stand at Entre Ribeiras, alt. 1450 m, 7.5 km NNW from here. The *Betula* trees in Covão da Metade have been planted about 25 years ago (you can see them from this site, ca. 1 km to the west); those along the road from here to Nave de Santo António seem to me to be sub-recent re-growth, probably after plantation (1 km to the south; you will see them very soon); those along the upper branches of Rio Mondego and around Penhas Douradas were planted and have expanded subsequently (2-5 km north and west of Manteigas). Batista (1982) mentions natural *Betula* expansion in the Candeeira valley, after having been absent at the end of the last century.

Ecology. Most *Betula* trees, both planted, semi-natural and natural, are now found in the wetter (formerly glaciated) part of the mountain, along streams and on peaty soils, often in sheltered gullies, between 1100 m and 1550 m altitude. The species (*Betula alba* according the most modern Iberian Flora, which includes the many forms of *B. pubescens* and *pendula* (= *verrucosa*)) seems therefore to be associated here with wet climatic and soil conditions. This is in agreement with its present-day distribution over Europe: it is abundant in cold and wet parts.
History. The history of *Betula* as can be read from our diagrams will be discussed later in more detail. What is relevant here is that the pollen curves differ strongly between sites, also when the sites are close together (such as Lagoa Comprida 2 - Lagoacho das Favas, 50 m apart; Charca dos Cões - Lagoa das Salgadeiras - Lagoa Clareza 1, 1/2 km apart): pollen percentages can be quite high in one diagram and quite low in another for the same period of time. This suggests strongly that *Betula* trees were generally scarce, but that they were in many instances growing directly near the sites, i.e. on the shores of the lakes of study. This is in agreement with the ecology scetched above. It will be discussed later how the differences between sites can be interpreted in terms of altitudinal zonation of vegetation, climatic history and history of human action.

Rye fields (*Secale cereale*)

Rye (*Secale*) fields are found scattered in the mountains up to 1600 m altitude or even higher. Many have been deserted in recent times, e.g. those near to the Lagoa Comprida 2 site. A complete production cycle of rye takes more than a year; each field produces a crop every second year. This results in the characteristic "bichromous" pattern of the fields: green and brown in spring, yellow and brown in summer and autumn. A characteristic weed is the grass *Micropyrum patens*. Rye cultivation is among the major causes for soil erosion in the area (Pinto da Silves & Teles 1980).

VIEW OVER ZÊZERE VALLEY

Stop 2

The upper valley of Rio Zêzere south of Manteigas is a classic example of a U-shaped glacial valley. This phenomenon is such a rarity in Portugal and even in the Serra da Estrela, that it is indicated as such on touristic maps.

DEGRADATION PHASES OF HEATHLAND

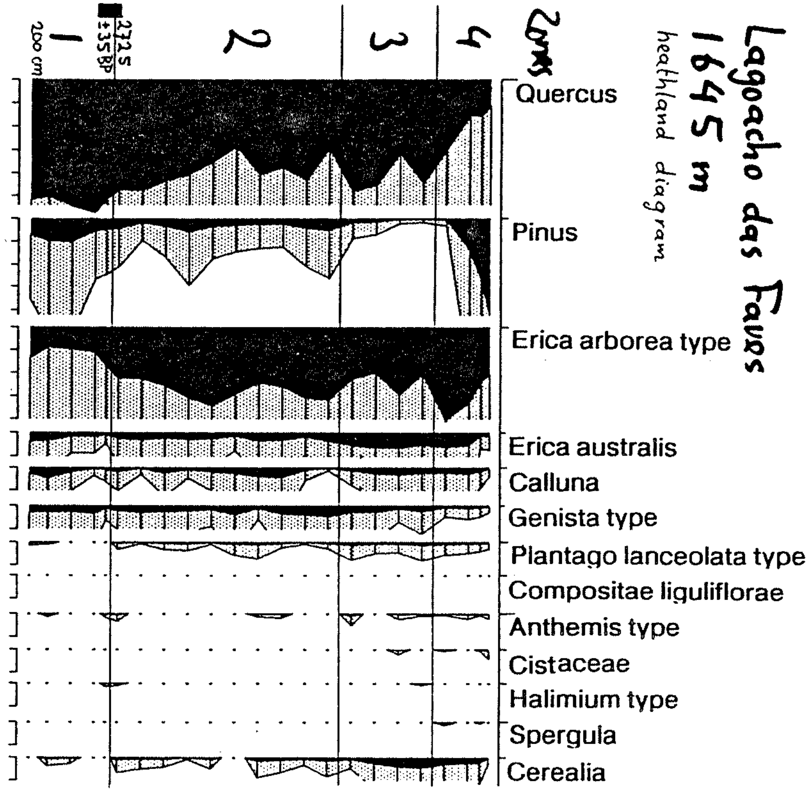
Stop 3

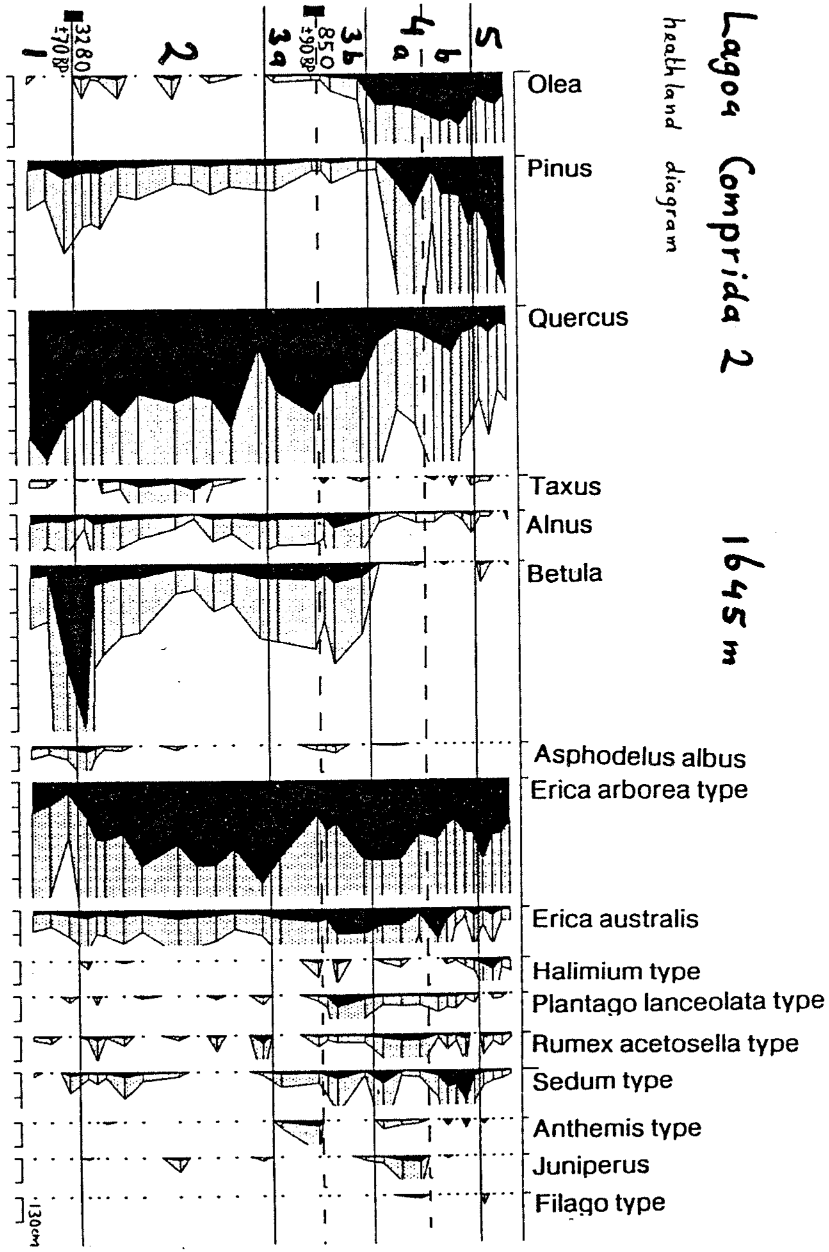
Pim van der Knaap and Jan Jansen

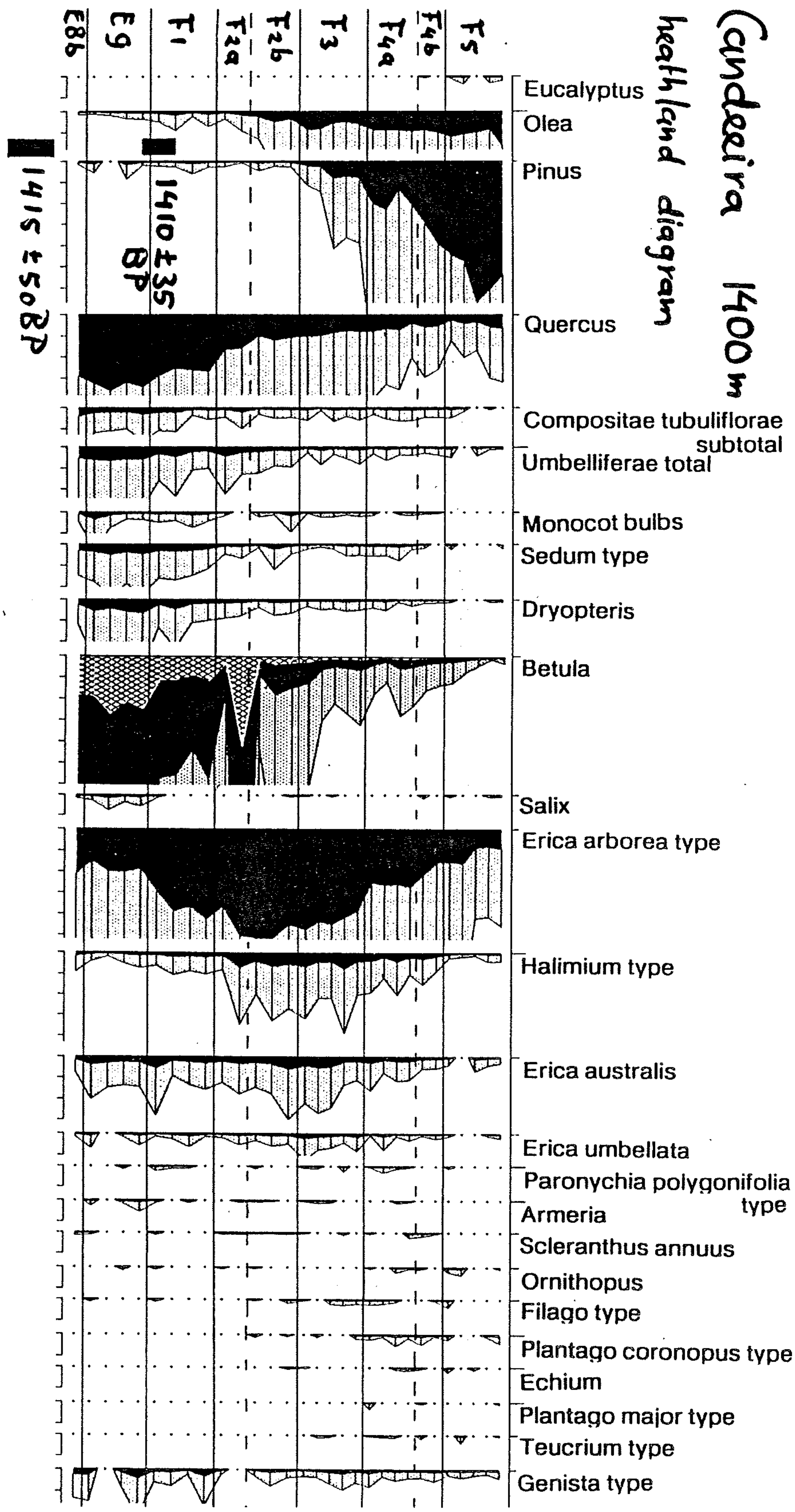
The degradation of "natural", spontaneous vegetation can be divided in a number of phases which can be recognized both in the field and in the pollen diagrams:

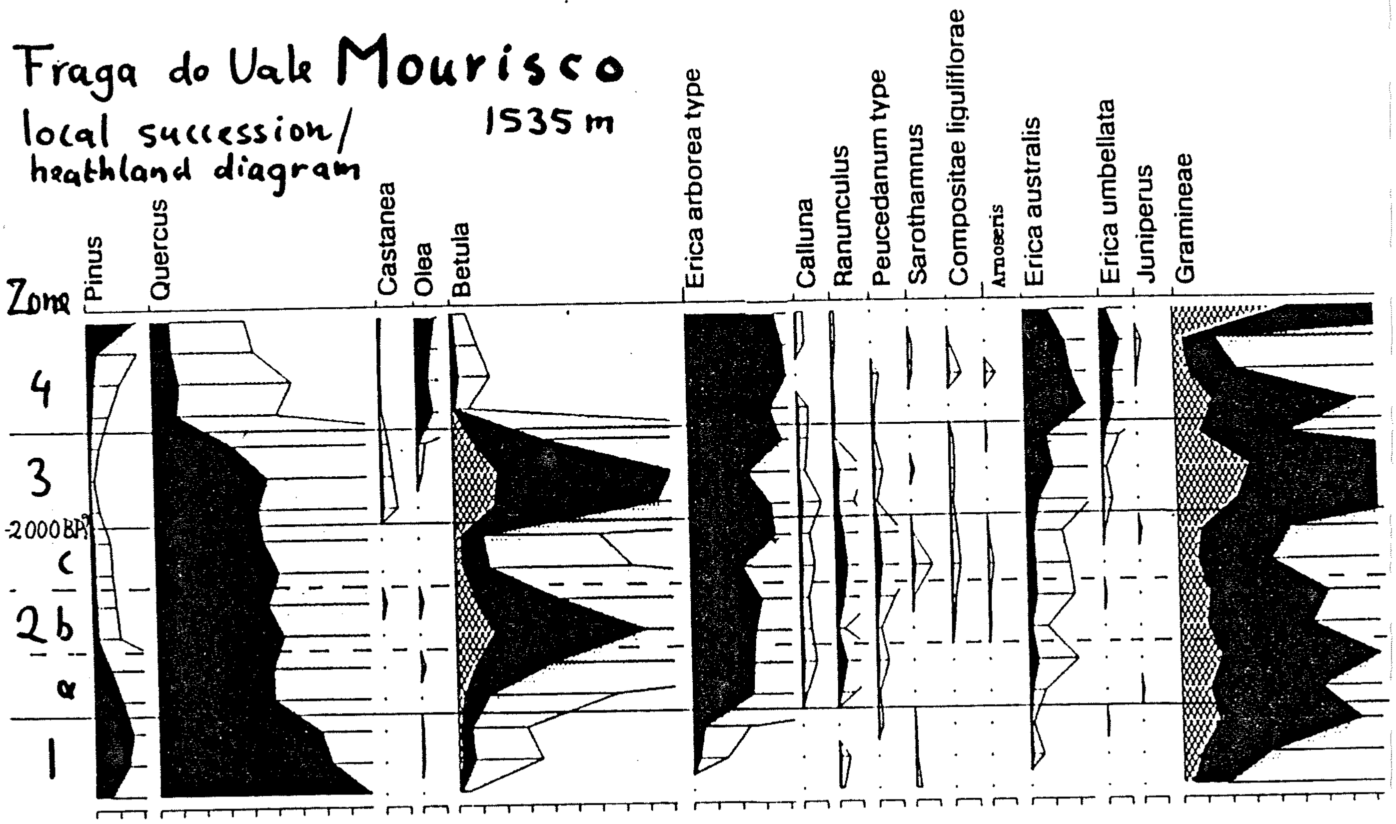
***Erica arborea* heathland**

Erica arborea heathland grows today on one-metre thick organic soils, which are nowadays found exclusively in valleys and along streams. These soils are therefore always moist. This heathland type is not very common in the Serra da Estrela. The pollen diagrams suggest, however, that this vegetation type (and therefore these soils) have had a considerably greater expansion in a certain stage of degradation of the landscape. This stage is placed in time following a phase of strong deforestation and preceding the expansion of vegetation types typical for mineral soils. It is therefore inferred that this temporary *Erica arborea* expansion took place on former forest soils directly following deforestation, before the greater part of these organic soils themselves were eroded away. In this way it is explained why thick organic soils are found today on moist places exclusively: on drier places such soils have invariably been eroded away, either directly through grazing or agriculture, or indirectly by fires.


Lagoacho das Favos
1645 m
heathland diagram
1
2
3
4
2725 ±35 BP
200 cm
Quercus
Pinus
Erica arborea type
Erica australis
Calluna
Genista type
Plantago lanceolata type
Compositae liguliflorae
Anthemis type
Cistaceae
Halimium type
Spergula
Cerealia


Lagoa Comprida 2
1645 m
heathland diagram
1
2
3a
3b
4a
b
5
3280 ±70 BP
850 ±90 BP
130 cm
Olea
Pinus
Quercus
Taxus
Alnus
Betula
Asphodelus albus
Erica arborea type
Erica australis
Halimium type
Plantago lanceolata type
Rumex acetosella type
Sedum type
Anthemis type
Juniperus
Filago type


Candeira 1400m
heathland diagram
E8b
E9
F1
F2a
F2b
F3
F4a
F4b
F5
1410±35 BP
1415±50BP
Eucalyptus
Olea
Pinus
Quercus
Compositae tubuliflorae subtotal
Umbelliferae total
Monocot bulbs
Sedum type
Dryopteris
Betula
Salix
Erica arborea type
Halimium type
Erica australis
Erica umbellata
Paronychia polygonifolia type
Armeria
Scleranthus annuus
Ornithopus
Filago type
Plantago coronopus type
Echium
Plantago major type
Teucrium type
Genista type



Erica arborea heathland is up to 3 m high. *E. arborea* dominates; *E. australis* is present in smaller quantities. The herb layer has a low cover and contains only a few species also present in Matt-grass (*Nardus stricta*) lawns: *Polygala serpyllifolia*, *Potentilla erecta*, *Ranunculus ollissiponensis* and *Galium saxatile*. Sometimes *Arenaria montana* is found, which is also a woodland species.

Another vegetation type on thick soils is *Genista florida* broom scrub. Unfortulately, this vegetation type is hardly represented in the pollen diagrams. The reasons are that (1) the *Genista* pollen type is produced by the many species of *Genista*, *Cytisus* and *Chamaespartium*; (2) only small quantities of *Genista* type pollen is found due to low pollen productivity and/or dispersal of all species involved. Therefore, broom scrub in general is very much "under-represented" in pollen diagrams.

Shepherds know of course that the most fertile soils are found below the above-mentioned vegetation types. These vegetations are therefore eagerly burned in order to create good grasslands for grazing. In this way, the well-developed *Erica arborea* heathlands degrade into the next stage:

Erica australis heathland

Erica australis heathlands are often growing at the periphery of *Erica arborea* heathland and form a zone of transition to even more degraded vegetation types, but they are also found over considerable surfaces in shallow depressions. *E. australis* heathland grows today on medium thick (or medium thin) organic soils (about half a metre). In the field, this vegetation is often patchy in character and rarely homogeneous, it has many shrub species (*E. arborea*, *E. umbellata*, *Calluna*, *Genista anglica*, etc.), and the ground surface is uneven. The vegetation is about one metre high. These characteristics confirm the idea that the vegetation type is in a process of degradation. In several pollen diagrams, an expansion of *Erica australis* follows an *E. arborea* expansion.

Erica umbellata heathland

The next degradation stage is *Erica umbellata* heathland, growing on thin organic soils (up to a few tens of centimetres). In the field, this vegetation forms at many places a transition between *E. australis* heathland and the next degradation stage, i.e. degraded open grasslands with many therophytes. *Erica umbellata* heathlands grow usually in a mosaic- complex with those degraded open grasslands. The shrub layer is rather low (a few tens of cm). *Calluna*, *Erica australis* and *Halimium alyssoides* are usually present, less frequent are *Cytisus purgans*, *Chamaespartium tridentatum*, *Genista anglica*, *G. florida* and *Erica arborea*.

Degraded open grasslands with many therophytes

The next degradation stage are degraded open grasslands with many therophytes. It grows on shallow organic soils. The soil surface is usually covered with a white gravel, the most erosion-resistent fraction of granite. Typical species are *Arnoseris minima*, *Filago minima*, *Aira praecox* and *Sedum arenarium*. Frequently present are *Molineriella laevis*, *Agrostis duriaei*, *Micropyrum tenellum*, *Sedum brevifolium*, *Teesdalia nudicaulis*, *Anthoxantum aristatum*, *Rumex angiocarpus*, *Ranunculus nigrescens*, *Spergula morisonii*, *Arenaria querioides = aggregata*, *Hieracium castellanum*, *Hypochaeris glabra*, and occasionally *Cerastium gracile*, *Poa bulbosa*, *Tuberaria guttata*, and many others. This vegetation type is at places invaded by scrub of *Halimium alyssoides*.

This stage of degradation is in the diagrams recognized primarily by the decline of pollen of a host of species preferring organic soils, mainly shrubs and herbs. The emergence of annual species is reflected in the diagrams, but rather weakly, since these plants have a low pollen production/dispersal.

TORRE, SUMMIT OF ESTRELA
Stop 5

The highest mountain of the Serra da Estrela and of Portugal is called Torre (or tower). This is because a tower has been built on top of it in order to reach 2000 m altitude. Some sources state that the Torre is 1992 m high and the tower on it 8 m. Other sources mention 1993 m and 7 m respectively, still others have 1991 m and 9 m; the highly desired 2000 m are attained anyway. Tourism and associated commercial activities have caused tremendous pollution with all kinds of rubbish on top of the Torre, but local organizations (the "Parque Natural" and the "Amigos" of the Serra da Estrela) have taken action to clean up everything and prevent further pollution. So whatever you think of it now, it has been far worse in the near past.

VEGETATION ABOVE 1800 M
Stop 6

General remarks

Above 1400 m altitude in the Serra da Estrela, plant-growth conditions become increasingly more difficult with increasing altitude. The existence (here: former existence) of a tree limit is an expression of this phenomenon. Another expression is the convergence of vegetation types towards the summits. With this I mean, that vegetation types which are clearly differentiated at a lower altitude, loose their differentiating characteristics with increasing altitude. This happens in two ways: (1) A number of differentiating and character species lagg behind and do not climb the mountains. The explanation for this is that such species tend to be demanding and usually have a narrow ecology; that is why they can differentiate. (2) With increasing altitude, vegetation types tend to incorporate differentiating species from other vegetation types. The explanation for this is that climatic conditions become more extreme with increasing altitude. Climate is here the dominant factor determining the composition of vegetation.

A well-known example from many mountainous areas is that of exclusive woodland species coming out of the forests above the tree limit. This can not be observed in the Serra da Estrela any more, due to the complete absence of forests above 1400 m altitude (*Pinus* plantations are not forests, of course, and anyway, they are burnt now for the greater part). An example which *can* be observed in the Serra da Estrela is that of heathlands and mires, which are clearly differentiated at 1400-1700 m altitude, but merge into each other at 1800-1900 m.

Peat mires on Torre

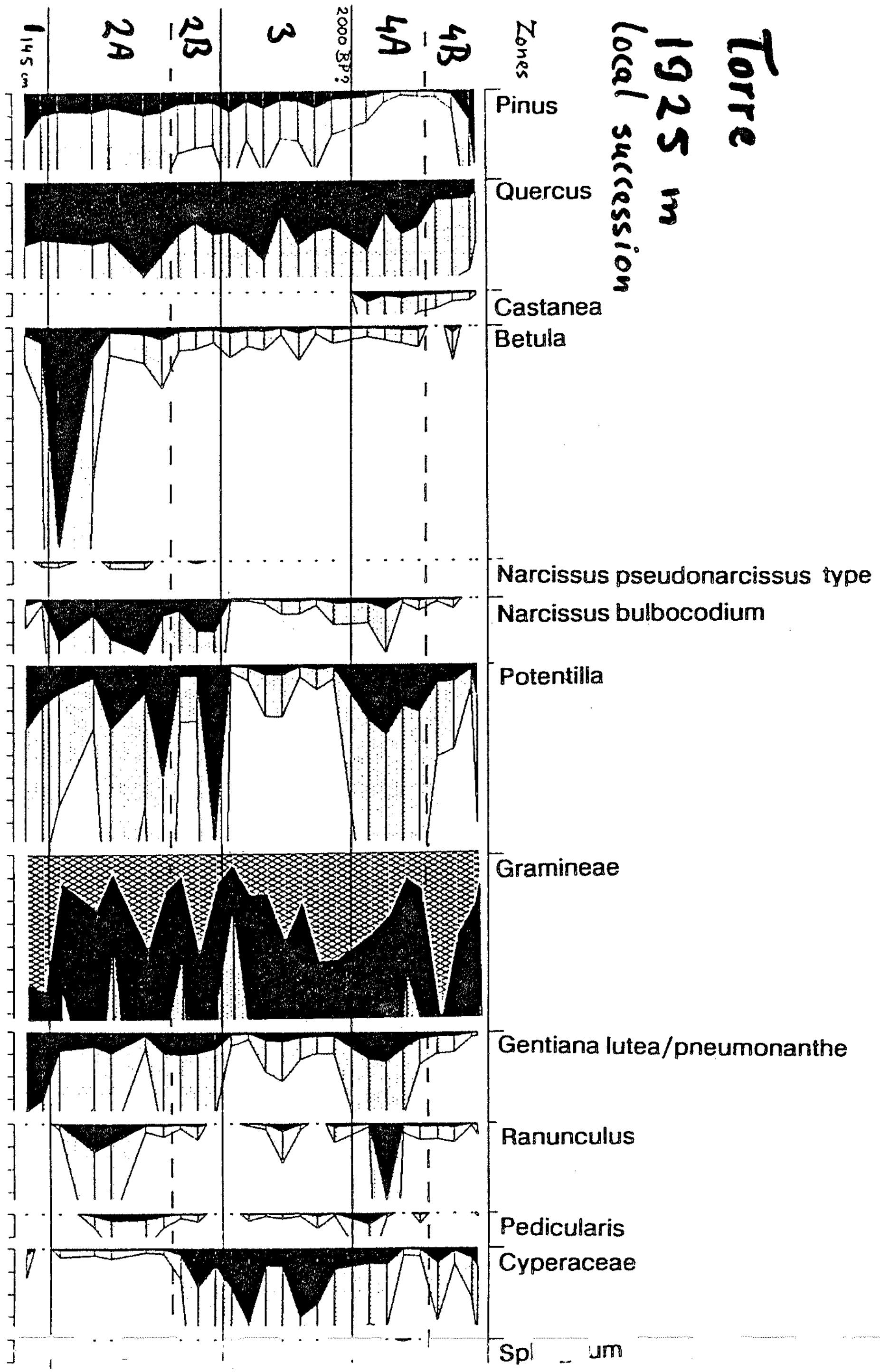
A remarkable type of peat mire is present in the Serra da Estrela above 1800 m altitude. String-hollow patterns are observed in small streams and around wells on slopes. The peat-growth patterns is such that it creates a number of pools of a few square metres lying in steps below each other; these step-pools are one to two dm below each other and are separated by peat wall two to ten dm broad and a few dm high. Water seeps slowly through the peat walls from one pool to the next. The peat walls are therefore wet the entire summer and can continue to grow. The peat walls are generally elevated above the peat surfaces at the side of the pools. It seems that in this mountain precipitation alone is not enough to keep peat growing; precipitation may be above 3000 mm annually, but the Mediterranean sun dries peat and makes man and woman thirsty. A discussion of the growth history of this peat mire is supported by the pollen diagram.

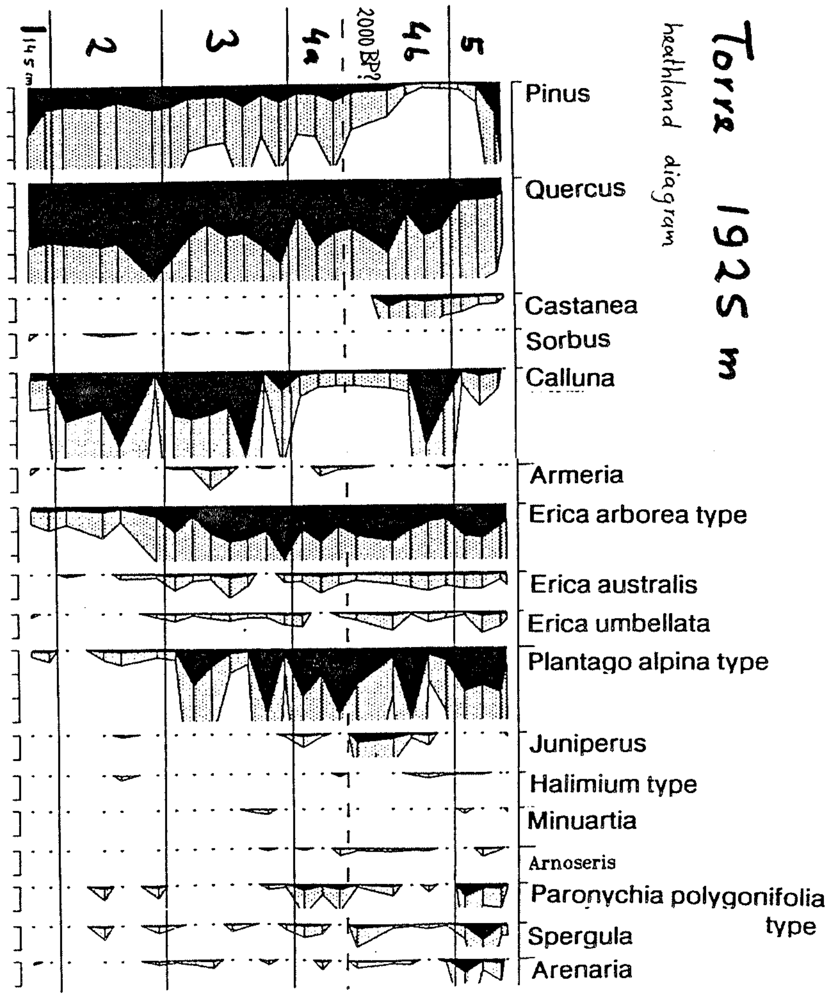
For a more general, more deep-digging and certainly more lengthy account on peat-forming vegetations in Portugal, I refer to the chapter written by Hans Joosten earlier in this excursion guide.

Degradation of vegetation on Torre

The degradation phases of vegetation at 1900 m altitude are different from those at 1600 m, which is an expression of altitudinal zonation. The following phases can be observed in the field:
Juniperus scrub (low, creeping Junipers), with no or very few other (dwarf-)shrubs.
Mat-grass lawns (closed *Nardus* fields). (a) Dry form (Galio-Nardetum) with *Narcissus bulbocodium*, *Juncus squarrosus*, *Galium saxatile*, *Potentilla erecta*. (b) Moist form (Junco-Sphagnetum compacti) with the same species and *Sphagnum* spp., *Aulacomnium palustre* and more *Narcissus bulbocodium*.
Open vegetation. (a) Agrosto-Minuartietum recurvae (fragment) on thick organic soils with dominant *Plantago radicata* (or *penyalarensis*; a plant resembling a small *P. alpina*) and *Minuartia recurva*. (b) Arenario-Cerastietum ramosissimi on fine granitic gravel, with *Arenaria aggregata*, *Agrostis durieui*, *Paronychia polygonifolia*, *Arnoseris minima*, *Rumex angiocarpus* (= *R. acetosella* s.l.), *Sedum* div. spec.

The Torre pollen diagram (1925 m) tells a different story. *Plantago radicata* seems to have expanded rather early (4500 BP??), probably as a result of grazing. The simultaneous increase to moderately high pollen values of *Erica* species could indicate grazing at somewhat lower altitude; I don't think that *E. arborea* and *E. australis* could have grown abundantly above 1900 m altitude. *Calluna* seems to have been common already before the beginning of grazing, but it declines at the first increase of types indicating soil erosion: *Juniperus*, *Halimium* type and a few tiny herbaceous species. In the end, soil erosion becomes to strong even for *Juniperus communis* and *Halimium alyssoides*, as is suggested by a reinforced increase of above-indicated and other small herbaceous species.


Torre
1925 m
local succession
Zones
1 145 cm
2A
2B
3
2000 BP?
4A
4B
Pinus
Quercus
Castanea
Betula
Narcissus pseudonarcissus type
Narcissus bulbocodium
Potentilla
Gramineae
Gentiana lutea/pneumonanthe
Ranunculus
Pedicularis
Cyperaceae
Spl um

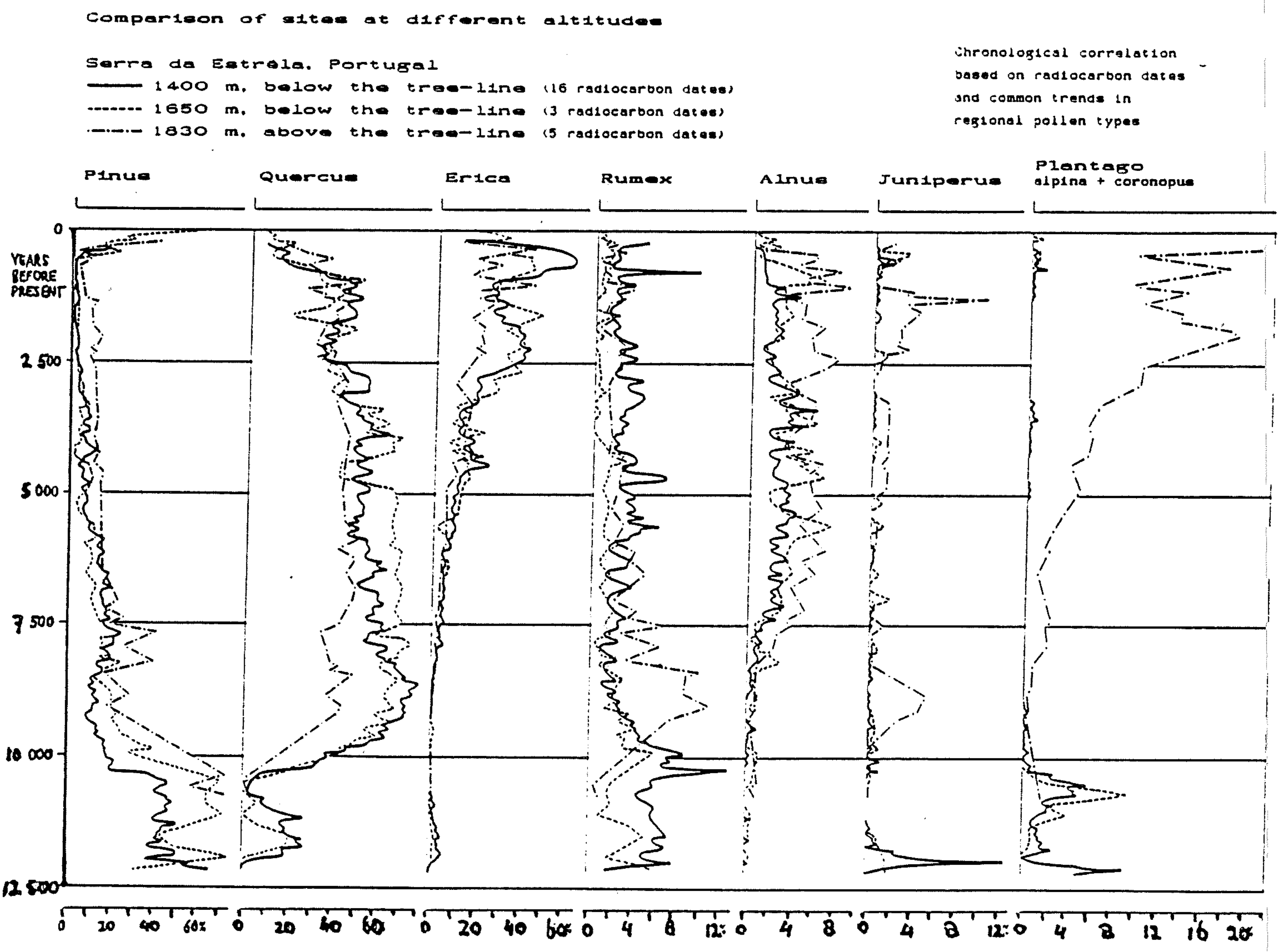

Torre 1925 m
heathland diagram
1 145 cm
2
3
4a
2000 BP?
4b
5
Pinus
Quercus
Castanea
Sorbus
Calluna
Armeria
Erica arborea type
Erica australis
Erica umbellata
Plantago alpina type
Juniperus
Halimium type
Minuartia
Arnoseris
Paronychia polygonifolia type
Spergula
Arenaria

FOREST LIMIT?
Stop 7

During this walk we will have an overview over sites at different altitudes, if wheather conditions allow:
- Lagoa **Clareza 1**, 1855 m
- Lagoa das **Salgadeiras**, 1835 m
- Charca dos **Cões**, 1795 m
- Lagoa do Peixão, 1645 m (coring in progress)
- (Charco da) **Candeeira**, 1400 m (in the distance)

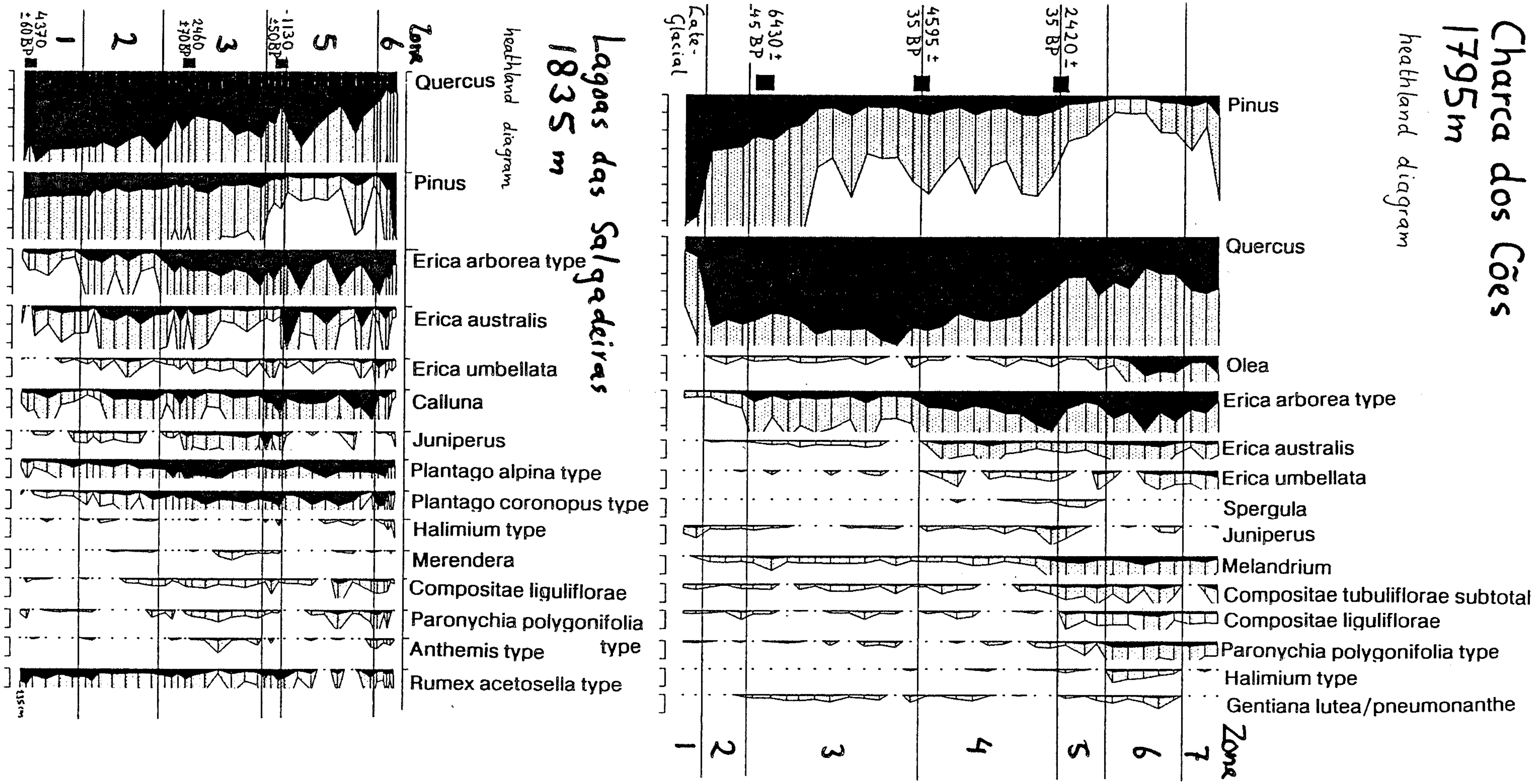
Forest limit

Complete pollen diagrams should are needed in order to establish the former forest limit and the history of forest destruction. A separate comparitive figure can be of help; it includes selected pollen curves on a time scale derived from Candeeira (1400 m), Lagoa Comprida 2 ("1650 m") and Lagoa das Salgadeiras ("1830 m").



Heathland succession

The succession of heathland vegetation is illustrated with diagrams from Lagoa das Salgadeiras (1835 m) and Charca dos Cões (1795 m). The succession at these sites has more in common with that on the Torre (1925 m) than at lower altitudes (Candeeira, 1400 m; Lagoa Comprida 2, 1645 m; Lagoacho das Favas, 1645 m). See e.g. the curve for *Erica arborea* type. From this you can conclude ...


Lagoas das Salgadeiras
1835 m
heathland diagram
Zone
1
2
3
5
6
4370 ±60BP
2460 ±70BP
-1130 ±50BP
Quercus
Pinus
Erica arborea type
Erica australis
Erica umbellata
Calluna
Juniperus
Plantago alpina type
Plantago coronopus type
Halimium type
Merendera
Compositae liguliflorae
Paronychia polygonifolia type
Anthemis type
Rumex acetosella type
Charca dos Cões
1795m
heathland diagram
Late-Glacial
6430 ± 45 BP
4595 ± 35 BP
2420 ± 35 BP
Pinus
Quercus
Olea
Erica arborea type
Erica australis
Erica umbellata
Spergula
Juniperus
Melandrium
Compositae tubuliflorae subtotal
Compositae liguliflorae
Paronychia polygonifolia type
Halimium type
Gentiana lutea/pneumonanthe
1
2
3
4
5
6
7
Zone

LAGOA COMPRIDA
Stop 8

Today we will visit the area north of Lagoa Comprida, 1650-1750 m altitude. This north-western part of the plateau seems to have a somewhat wetter climate than other parts. I conclude this from (a) the occurrence of a number of species with a northern distribution, which have here their only occurrence (or main distribution) in the Serra da Estrela or even in Portugal (*Vaccinium myrtillus*, *Veratrum album*, *Menyanthes trifoliata*, *Sphagnum russowii*, *S. girgensonii*), (b) the occurrence of many small peat mires, absent from other parts of the Serra da Estrela with similar altitudes.

Zonation and succession of aquatic and marsh vegetation

Zonation

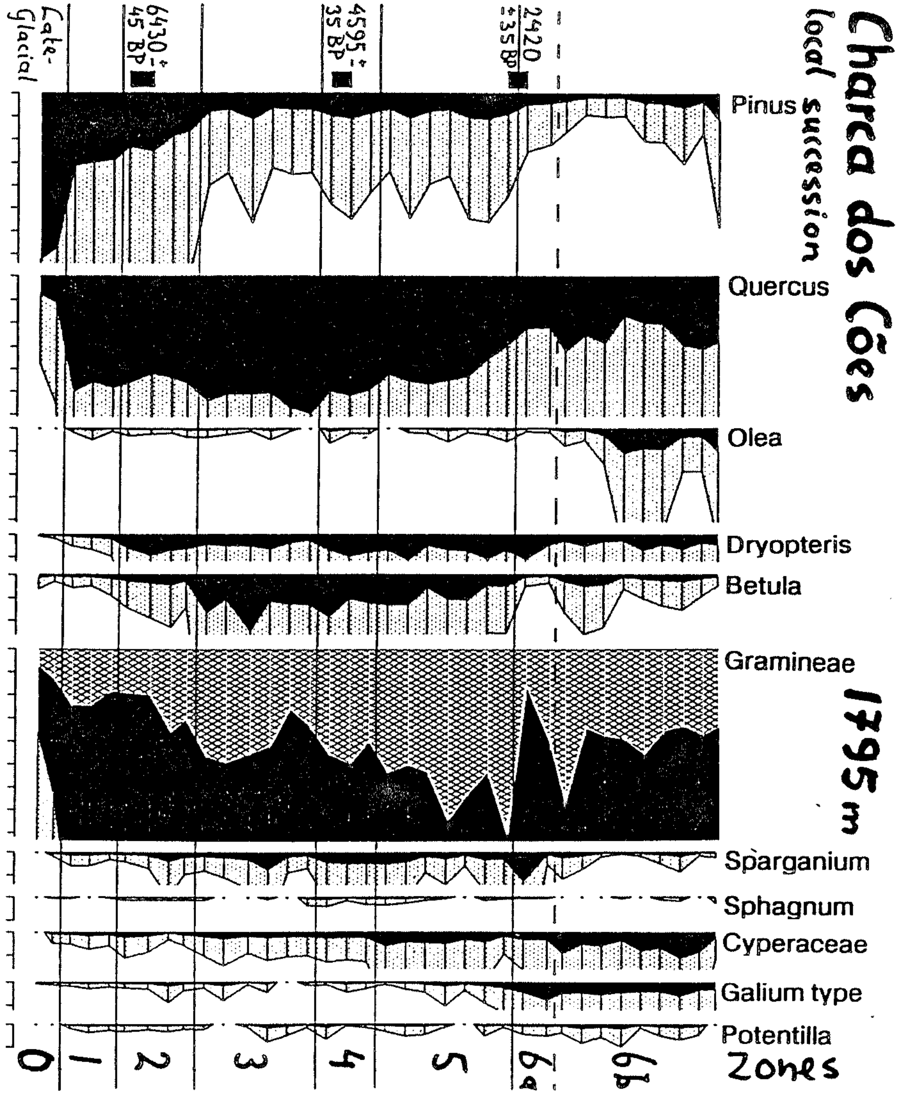
Aquatic and marsh vegetation is well-developed at the sites to be visited today. In Lagoa Redonda we will see the deepest zone with vascular-plant vegetation, where *Potamogeton polygonifolius* grows in 2-m deep water, together with *Sparganium angustifolium* with its floating leaves. A next zone is well-developed in the famous Lagoacho das Favas, the site where *Menyanthes trifoliata* grows in the deepest part of the lake (ca. 1 m deep) as a semi-aquatic plant; virtually the only site in Portugal. It grows mixed with *Sparganium angustifolium*. In a next zone with shallower water grows the aquatic grass *Antinoria agrostidea* ssp. *natans*, also with floating leaves, together with some *Ranunculus* subgenus *Batrachium*. This zone and most of the following can be observed in many of the lakes in the Serra da Estrela. In a next zone with very shallow water grows *Ranunculus* subgenus *Batrachium* in abundance, together with some *Antinoria*, *Juncus bulbosus* and *Drepanocladus fluitans*. This zone is dry in summer. Conspicuous (to some people at least) are the beards of *Fontinalis antipyretica* on the sides of semi-submerged rocks. The peaty lake margins form the next zone. This vegetation type is called Junco-Sphagnetum, and is characterized by *Juncus squarrosus*, *Sphagnum compactum* and others, and *Aulacomnium palustre*. *Narcissus bulbocodium* can be very abundant. What follows is a Galio-Nardetum, a similar vegetation but somewhat drier, without *Sphagnum* species and with higher quantities of herbs like *Potentilla erecta*, *Galium saxatile*, *Nardus stricta*, *Pedicularis sylvatica*.

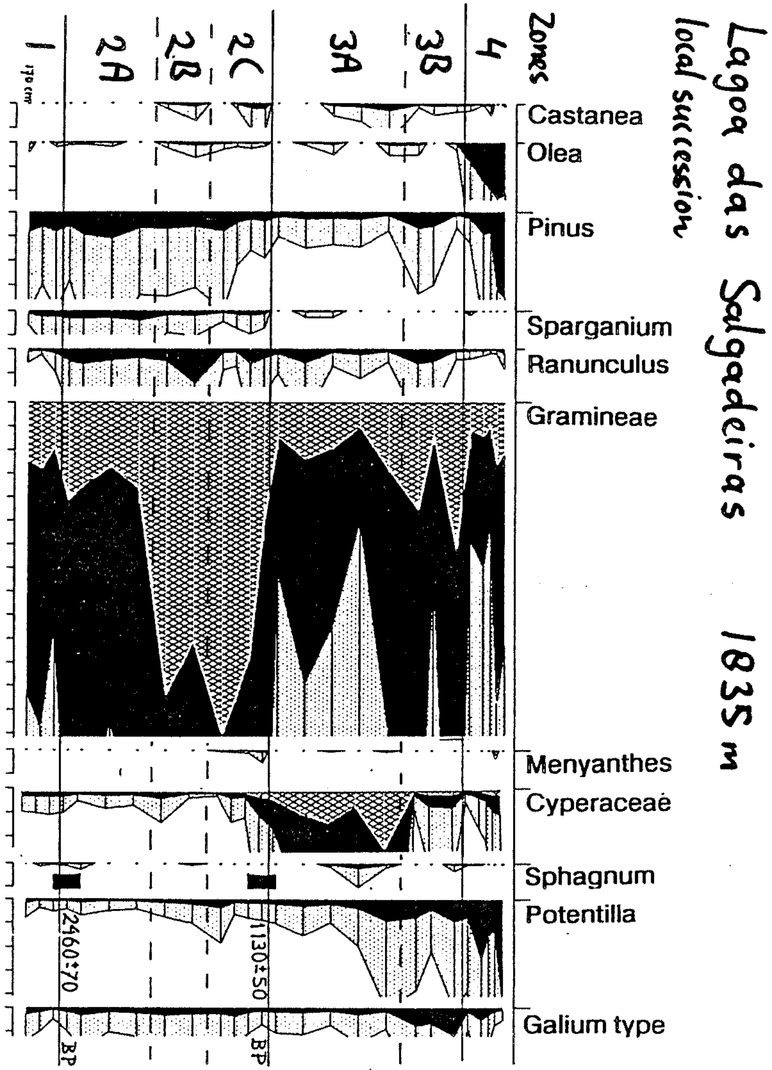
Succession

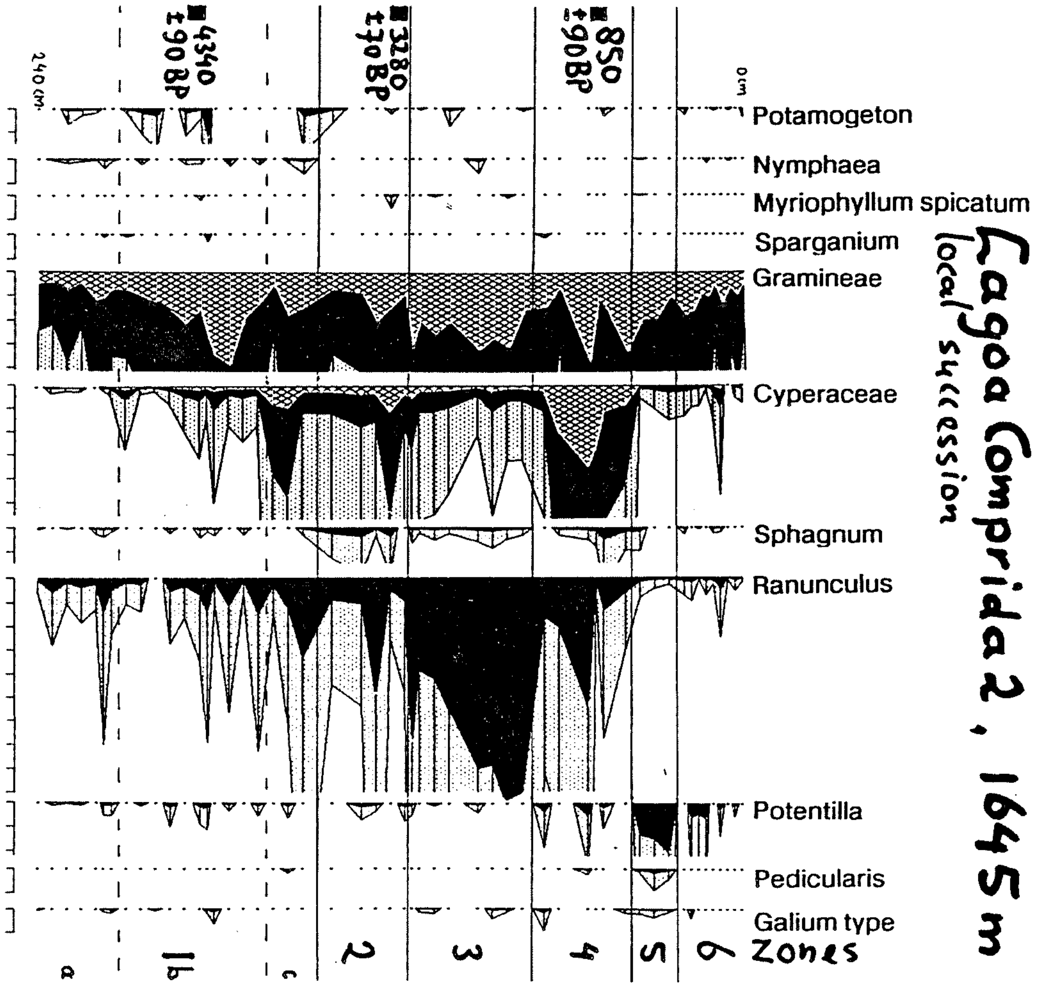
Look at the diagrams: the succession of aquatic and marsh vegetation follows the same stages as are observed in the above-described zonation. What are the differences? Are there differences in succession between altitudes?

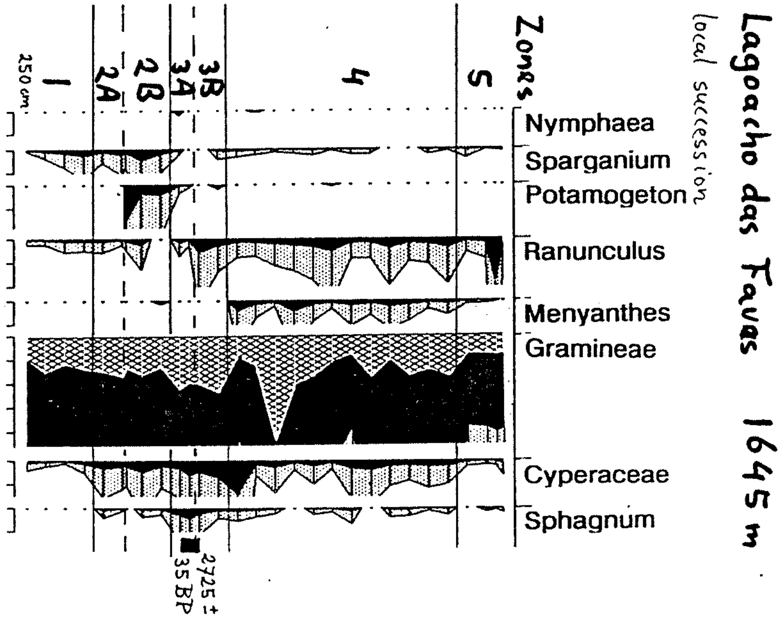
Betula

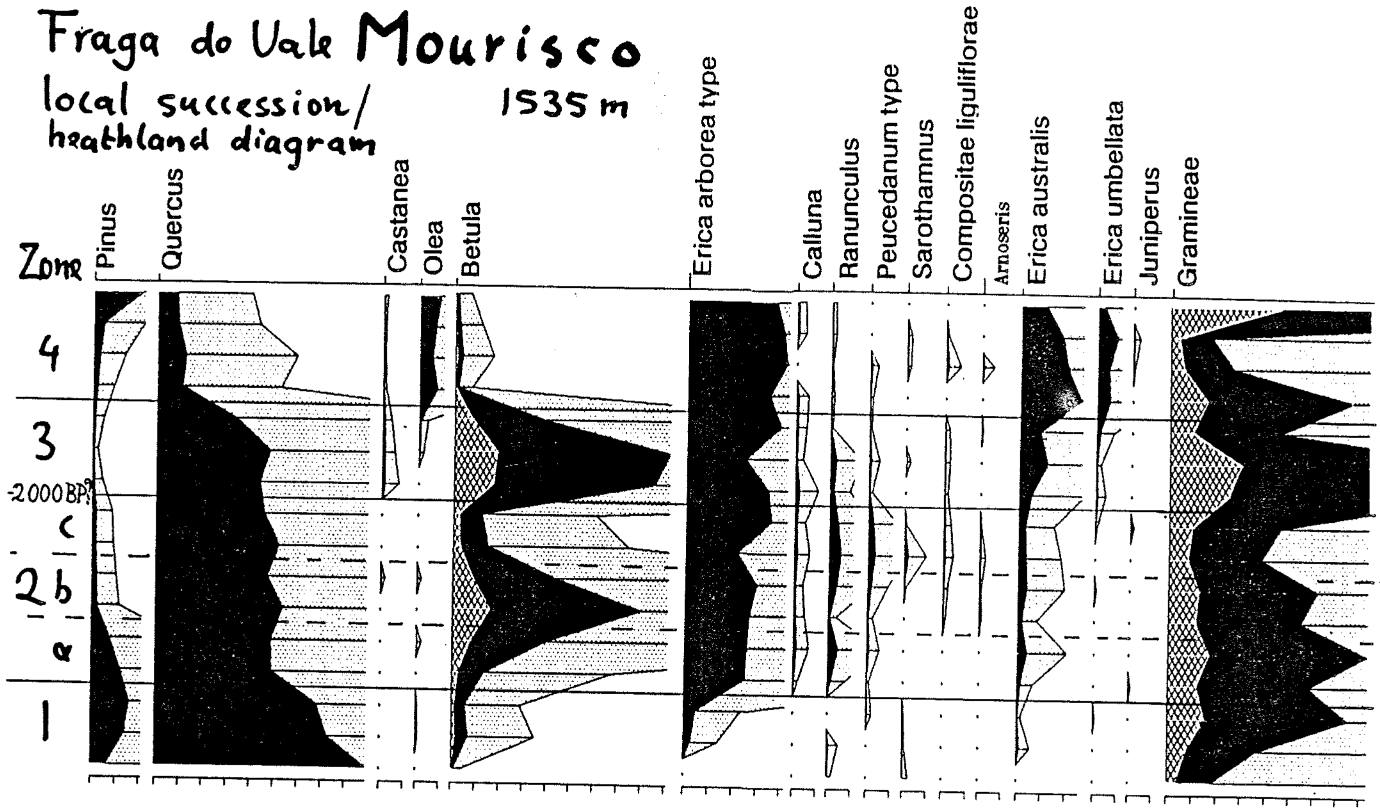
The diagram of Lagoa Comprida 2 (1645 m) is our second *and* second-largest diagram from the Serra da Estrela. The site of Lagoacho das Favas is located very nearby, 50 m to the south and at the same altitude. We studied this site in order to discover patterns in vegetation. We were immediately shocked by the remarkable difference in the *Betula* curve between the sites; from that time onwards we decided to exclude *Betula* from the pollen sum. Do you agree??


Charca dos Cões
local succession
1795 m
Late-Glacial
6430 ± 45 BP
4595 ± 35 BP
2420 ± 35 BP
Pinus
Quercus
Olea
Dryopteris
Betula
Gramineae
Sparganium
Sphagnum
Cyperaceae
Galium type
Potentilla
Zones
0
1
2
3
4
5
6a
6b

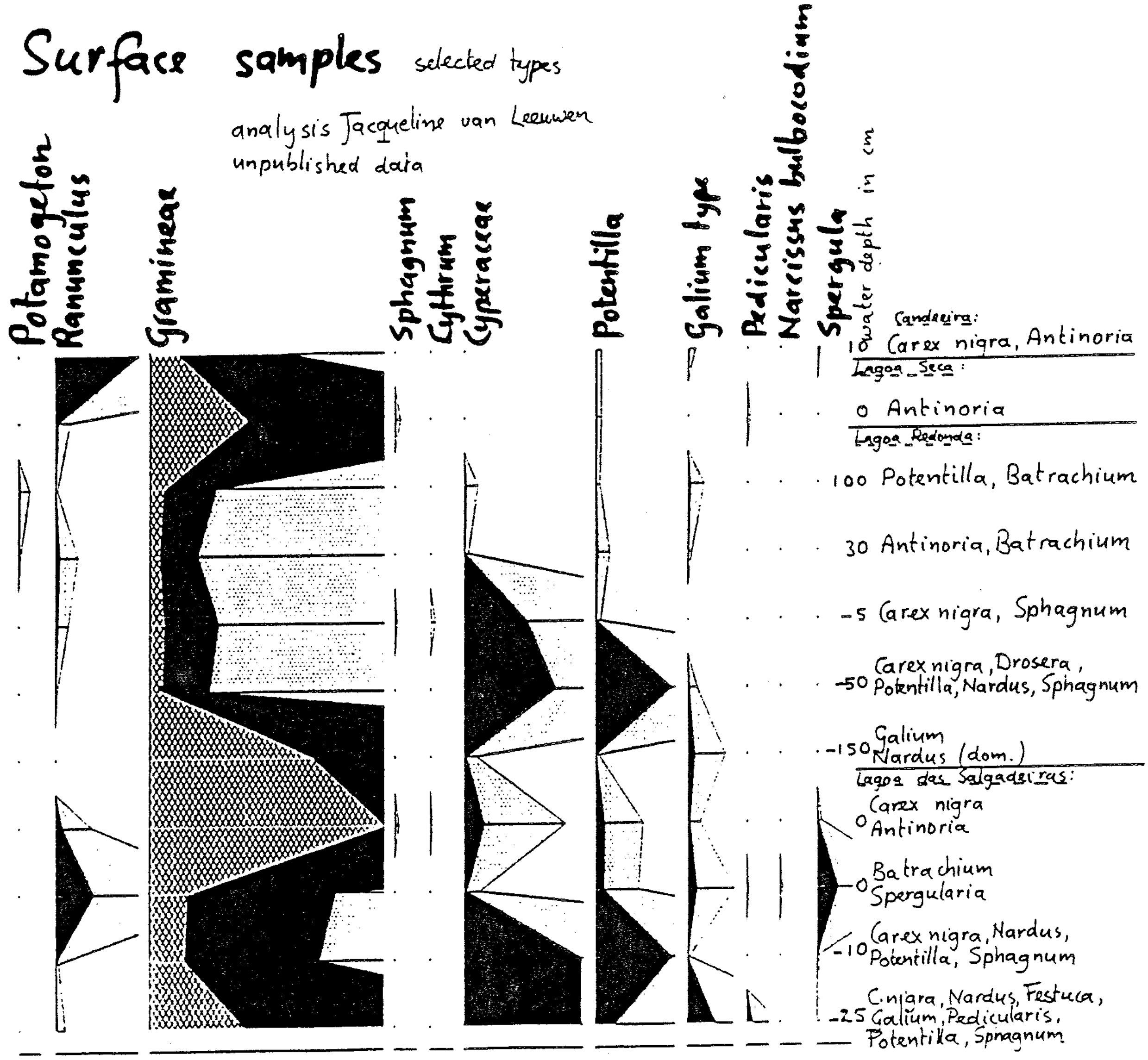

Lagoa das Salgadeiras
local succession
1835 m
Zones
1
2A
2B
2C
3A
3B
4
Castanea
Olea
Pinus
Sparganium
Ranunculus
Gramineae
Menyanthes
Cyperaceae
Sphagnum
Potentilla
Galium type
2460±70 BP
1130±50 BP


Lagoa Comprida 2, 1645m
local succession
0 cm
240 cm
850 ±90BP
3280 ±70BP
4340 ±90 BP
Potamogeton
Nymphaea
Myriophyllum spicatum
Sparganium
Gramineae
Cyperaceae
Sphagnum
Ranunculus
Potentilla
Pedicularis
Galium type
Zones
a
1b
c
2
3
4
5
6


Lagoacho das Favas 1645 m
local succession
Zones
250 cm
1
2A
2B
3A
3B
4
5
Nymphaea
Sparganium
Potamogeton
Ranunculus
Menyanthes
Gramineae
Cyperaceae
Sphagnum
2725 ± 35 BP



Fraga do Vale Mourisco
local succession/
heathland diagram
1535 m
Zone
4
3
-2000 BP?
c
2 b
a
1
Pinus
Quercus
Castanea
Olea
Betula
Erica arborea type
Calluna
Ranunculus
Peucedanum type
Sarothamnus
Compositae liguliflorae
Arnoseris
Erica australis
Erica umbellata
Juniperus
Gramineae



Surface samples selected types
analysis Jacqueline van Leeuwen
unpublished data
Potamogeton
Ranunculus
Gramineae
Sphagnum
Cythrum
Cyperaceae
Potentilla
Galium type
Pedicularis
Narcissus bulbocodium
Spergula
water depth in cm
Candeeira:
10 Carex nigra, Antinoria
Lagoa Seca:
0 Antinoria
Lagoa Redonda:
100 Potentilla, Batrachium
30 Antinoria, Batrachium
-5 Carex nigra, Sphagnum
-50 Carex nigra, Drosera, Potentilla, Nardus, Sphagnum
-150 Galium Nardus (dom.)
Lagoa das Salgadeiras:
0 Carex nigra Antinoria
0 Batrachium Spergularia
-10 Carex nigra, Nardus, Potentilla, Sphagnum
-25 C. nigra, Nardus, Festuca, Galium, Pedicularis, Potentilla, Sphagnum

CASAL DO REI: FOREST WALK

Our forest walk will be in the western outskirts of the Serra da Estrela, west of Loriga at altitudes between 350 and 500 m, between the villages of Cabeça and Casal do Rei. The walk will give you the opportunity to study both some very ancient, agricultural practices on steep slopes, and some very rare, relictual occurrences of laurophyllous forest. The Service for Nature Parks, Reserves and Conservancy published a booklet (in Portuguese) on the forest relics near Casal do Rei (Duarte & Alves 1989). In it, some forest types discussed in Pinto da Silva & Teles (1980) are exemplified for Casal do Rei with vegetation relevés.
Our walk will follow the valley of the stream of Ribeira de Loriga, which is approximately east-west orientated and is deeply incised into the schistose-grauwacke bedrock. Casal do Rei is one of the better-preserved old villages in Portugal, where modernization of life-style did not damage too much the ancient structure of the village and the cultural landscape. Most houses still have their original appearance from the outside, with their beautiful schistose building material, but modernization of the interiors can be guessed from the forest of television antennae on the roofs.
We will start in Cabeça, where also part of the old houses still has the old exterior. First we will walk 200 m down the slope. These south-exposed slopes are for the greater part intensively cultivated on narrow terraces separated by stone walls. Water supply for the fields on the terraces seems to be the most critical factor, which can be guessed from the intricately branched system of irrigation channels and the way the water is distributed with the help of stones and earth clods. Most fields are cultivated with several vegetable types at the same time and have their own olive tree rooted in the terrace wall above. Apart from agriculture, people make their living by keeping bees and small numbers of sheep and goats and by extensively using the forests on the opposite, north-exposed slope. In the forests, they collect some wood, fuel, pine resin, *Arbutus* fruits, chestnuts, bedding material for the livestock and maybe some herbs for cooking or medicinal purposes.
Two hundred metres below Cabeça we cross the bridge over Ribeira de Loriga. Here a narrow irrigation channel newly built in concrete (with precious E.C. money) branches off the main stream, leading to the fields of Casal do Rei a few kms to the west. The purpose of this channel is, enabling the people to continue in these modern times with their traditional type of agriculture on irrigated terraces. Apart from the building material, the channel is beautifully fit into the landscape.

We follow now in westward direction the north-exposed, forested slope to Casal do Rei. Original forests (undisturbed by man) are in Portugal extremely scarce or even absent. In the Serra da Estrela they have virtually disappeared; we were so lucky that the people of the Parque Natural da Serra da Estrela showed us here one of the last tiny remains. An acquaintance with such relictual forests is for us as palaeo-ecologists extremely useful, since it can give us clues about the forests having covered the Serra da Estrela during greater part of the Holocene period. Duarte & Alves (1989, p. 13) state that "It is in fact only through the analysis of small relics persisting here and at other places, that it is possible to reconstruct something of the past" (translation mine). We agree with this in that "The present is the key to the past", but they evidently forgot to mention palaeobotany as a tool for reconstruction. The remains of original forests are in fact very small and very relictual in character. The original forest communities have probably disappeared, but (part of?) the constituent species can still be encountered in a series of degradational stages. They will be discussed now:
1. *Prunus lusitanica* stands. We pass through two or three tiny remains of laurophyllous forest, situated in humid incisions into the north-exposed slope, where there is some seepage of water. The forest type is characterized by the evergreen trees of *Prunus lusitanica*, a rare Iberian endemic. Other evergreen trees present are *Arbutus unedo*, *Viburnum tinus*, *Ilex aquifolium*, *Quercus rotundifolia* (= *Q. ilex* s.l.) and a single *Quercus suber*. Remarkable are the huge *Castanea sativa* trees standing scattered in the forest, used for chestnut collection. For additional species, see next type.
2. *Quercus rotundifolia* forest. On less sheltered parts of this slope, we meet relictual forms of

Quercus rotundifolia forest, in which *Arbutus unedo* plays an important role and also the other evergreen trees mentioned above are present. Some species typical for this and the latter forest type are: climbers *Hedera helix* ssp. *canariensis* and *Lonicera periclymenum*; shrubs *Crataegus monogyna*, *Frangula alnus*, *Daphne gnidium* and *Ruscus aculeatus*; herbs *Asplenium onopteris*, *Blechnum spicant*, *Pteridium aquilinum*, *Primula vulgaris*, *Viola riviniana*, *Arenaria montana*, *Geum sylvaticum*, *Rubia peregrina*, *Luzula forsteri*, *Pulicaria odora*, *Narcissus triandrus* and *Orchis mascula*. The relictual character of the remains of these two forest types is evidenced by the occurrence of quite a few shrubs typical for heathlands on thick, former forest soils: *Erica scoparia*, *E. arborea*, *E. australis*, *Rubus ulmifolius*, *Sarothamnus grandiflorus*, *Phillyrea angustifolia*, *Genista triacanthos*, *Cistus populifolius*, *C. salvifolius*, *C. psilosepalus*, *Lavandula* (*stoechas* ssp.) *luisieri*, *L. pedunculata* and *Lithodora prostrata*.

3. *Arbutus unedo* high-scrub. More common than the two above-mentioned types is a degradational stage of the two, which is dominated by *Arbutus unedo*. A great part of the forest soils has been eroded. As a consequence, the above-mentioned forest trees, climbers, forest shrubs and forest herbs are usually absent, but part of the heathland shrubs mentioned for thick soils are still encountered occasionally. But there can be added a list of shrubs typical for heathlands on thinner soils: *Erica umbellata*, *Calluna vulgaris*, *Chamaespartium tridentatum*, *Helichrysum stoechas*, *Halimium alyssoides* and *H. ocymoides*; and a number of annual herbs also typical for thin soils: *Campanula lusitanica* and .*Anarrhinum bellidifolium*.

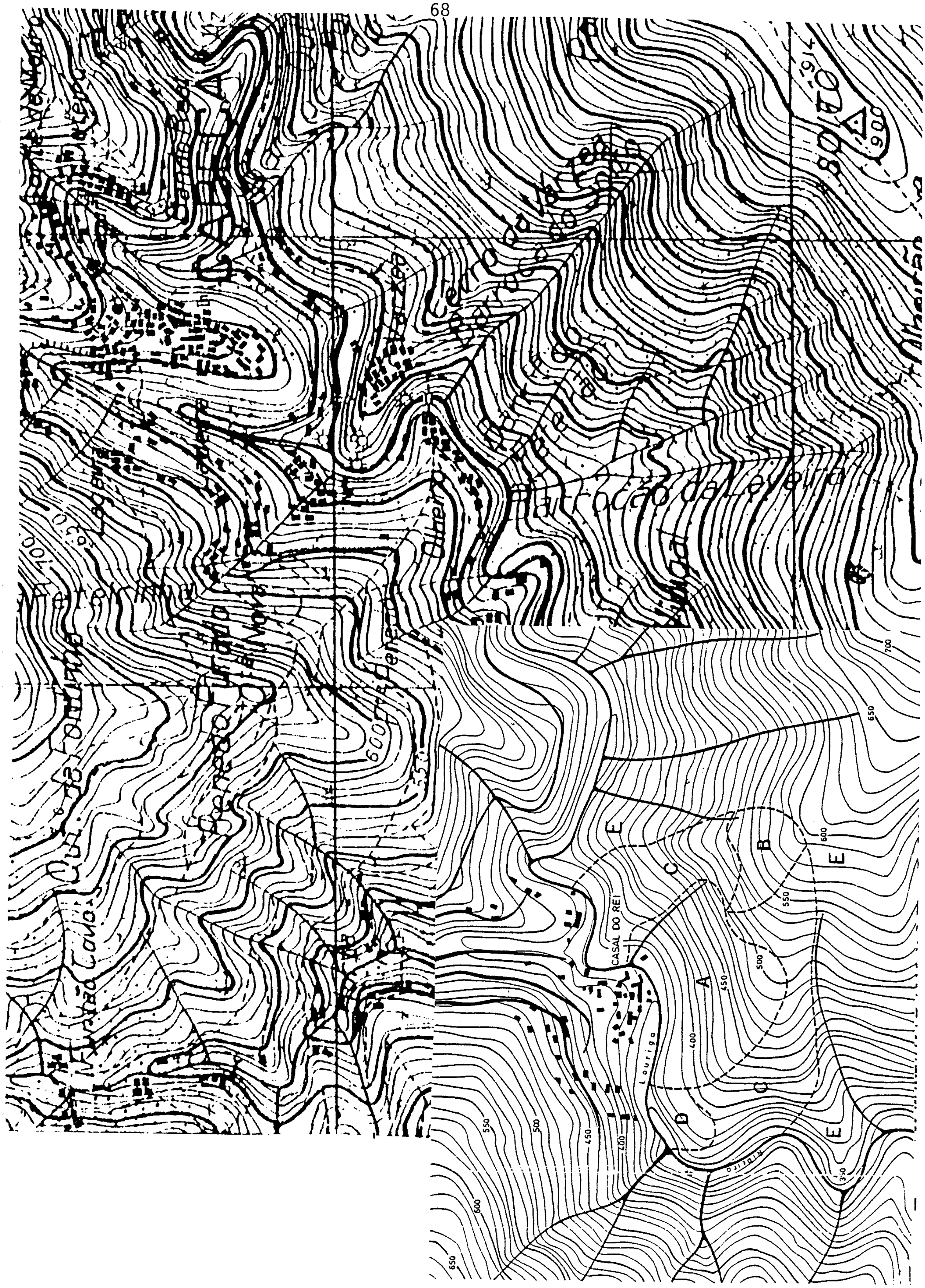
4. *Pinus* plantations. Pine plantations (also "forests") occupy much more space on the north-exposed slopes than the three above-mentioned types together. Pine plantations are poor in species; only those mentioned above for thin soils are found, together with a few additional species with a similar ecology: *Erica cinerea* and Monocot bulbs *Simethis planifolia* and *Scilla monophyllos*. All species encountered in pine plantations are common Mediterranean species with a wide ecology: nothing special! The resin-collection equipment attached to the trees shows a small evolution: formerly used earthen collection pots can still be found on the forest floor, if you are lucky; plastic collection pots of the same model are the most commonly used now; modern plastic collection bags are used in a few restricted areas.

5. Forests on wet soils. There is not much room in the narrow valley for forests on wet soils and we encounter only a little of what is present, since we cross the stream at two places only. We might encounter *Alnus glutinosa*, *Fraxinus angustifolia*, *Salix salvifolia*, *S. atrocinerea* and *Osmunda regalis*.

We passed several groups of bee-hives. Most (or many) of them are constructed of local materials, consisting of a body of cork and covered with a flat stone.

After crossing again the stream of Ribeira de Loriga, we ascend to the village of Casal do Rei and you can have a second look at the agricultural system. There is a wealth of plant species along the fields and irrigation channels and on the terrace walls: ask your guide!

The small pollen diagrams of Quinta da Alagoa and Zêzere, derived from the other (i.e., east) side of the Serra da Estrela, gives an impression of the pollen assemblage related to a semi-forested cultural landscape such as we saw today. We don't have radiocarbon dates and a dating through comparison with other diagrams appears to be difficult due to the rather unique pollen assemblages in this diagram. Nevertheless, it could be synchronous with zones F2 and F3 of the Candeeira diagram, which include the first plantation of *Pinus* some centuries ago. The decline of *Castanea* could be a reflection of the transition from chestnut collection towards chestnut coppice.



unpublished manuscript

The vegetation succession since Late-Glacial times in the Serra da Estrêla, Portugal, studied on the lake of Charco da Candeeira (1400 m a.s.l.)

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Abstract

The vegetation succession from 12 500 BP up to the present day in the Serra da Estrêla, a granitic mountain in central east Portugal, is reconstructed based on pollen diagrams from lake deposit of a small lake at 1400 m a.s.l. The reconstruction is based on knowledge of the flora, of the ecology of plant species and the region, and of production and dispersal properties of pollen types. Nearly 200 pollen types were encountered in 316 samples. Six main periods of vegetation succession were distinguished: A (7 pollen assemblage zones; Late-Glacial comprising part of Bølling, Older Dryas, Allerød, Younger Dryas): Climate-induced successions from polar desert to savannah and back to steppe, under cool and dry, continental climatic conditions. B (4 zones): Succession from steppe to forest under warm and rather dry climatic conditions and without interference of man. C (10 zones): Forests; climate turns moister and cooler and is the main factor determining the forest dynamics. The anthropogenic factor starts to play a minor but increasing role. D (7 zones): The area covered by forests is hardly affected by man, but the forest dynamics as read from the diagram are predominantly human-induced: there is some grazing in the forests and there are small-scale local deforestations. E (9 zones): Large-scale deforestations take place, but the forests retain their capacity to regenerate. Deforestation phases, stable phases and forest-regeneration phases succeed each other, in relation to changing patterns and intensity of human pressure. F (5 zones): Anthropogenic pressure increases to such an extent that the forests virtually disappear and organic soils are for the greater part eroded and flushed away. The main agents are grazing, burning, agriculture and large-scale plantation of pines.

Vegetation and its zonation

Nomenclature of vascular plants follows the Flora Europaea. The vegetation of the Serra da Estrêla consists of heavily grazed and frequently burnt heathlands, broom scrubs, grasslands and pine plantations, which are generally thought to have replaced *Quercus* forests up to a forest limit somewhere between 1600 m and 1900 m (Braun-Blanquet et al. 1952, Pinto da Silva & Teles 1980); the highest historically-documented, usually isolated *Quercus pyrenaica* trees were and are found at 1750 m a.s.l. (Batista 1982). A clear zonation can be distinguished in the vegetation, based on the tiny forest remains and on the replacement vegetation (l.c.). This zonation follows not only the altitudinal pattern as is usual in mountains, but it is also 'concentric', i.e. centred around the highest part of the mountain. There are two causes for this concentric zonation. One is climatic: the climate is increasingly wetter and cloudier (more oceanic) towards the centre of the mountain, not only at the summits, but also in lower valleys in the central part. In the direction of the centre it is therefore also wetter and cloudier at similar altitudes and the vegetation shows corresponding differences. A second cause for this concentric zonation is the local geology. The central, formerly glaciated part of the Serra da Estrêla has a granitic bedrock which is very poor in minerals, whereas adjacent areas are predominantly schistose. These schists sustain thermophytic vegetations at higher altitudes than granites, since they are considerably richer in erodable minerals and heat up quicker in the sun.

The vegetation zonation is in broad lines as follows. The colline zone reaches from the foot of the mountain (400 m) up to 800 m altitude in the central part and up to 1000 or 1200 m altitude in the periphery. It is the domain of *Quercus rotundifolia* forests on south-exposed slopes and *Quercus pyrenaica* forests on north-exposed slopes. Most forests have disappeared; degradation stages progress through *Arbutus* and *Frangula* thickets, thermophytic heathlands, broom scrub, Cisto-Lavanduletea scrub, *Cistus-ladanifer* scrub, open vegetations belonging to the Tuberarietalia guttatae, and finally into bare rocks without vascular plants. A specialty of this zone are a few laurel-leaved forest remains between 450 and 900 m, including *Prunus lusitanica*, *Laurus nobilis*, *Ilex aquifolium*, *Arbutus unedo*, *Viburnum tinus*, *Quercus suber* and *Hedera helix* ssp. *canariensis*. *Alnus glutinosa* and *Fraxinus angustifolia* are locally present along streams. Many north-exposed slopes have extensive *Castanea* plantations; large areas are planted with pines. *Phillyrea angustifolia* is found mainly below 600 m. *Olea* and *Vitis* are widely cultivated up to an altitude of 900 m. Above this zone is the montane zone, reaching to 1600 m altitude in the central part and to the summits in the periphery (which are generally below 1600 m). The study site lies in this zone. It is the domain of *Quercus pyrenaica* forests, which are however represented only very fragmentary. Degradation stages progress through tall *Genista florida* and *Erica arborea* shrublands on thick organic soils (the former forest soils), *Cytisus* and *Erica australis* scrub on medium thick organic soils, *Chamaespartium tridentatum* and *Erica umbellata* heathlands on thin organic soils, *Halimium alyssoides*-dominated vegetations on inorganic soils, open grasslands, and finally to bare rocks without vascular plants. This zone has large pine plantations, which have an upper limit at about 1400 m. Along streams on organic soils are regularly found *Salix salvifolius* and *S. atrocinerea*, more locally *Fraxinus angustifolia*, *Betula alba* and very localized also *Taxus baccata*. *Ilex aquifolium* is rare. Scattered occurrences of *Sorbus aucuparia* are rather common. The upper montane zone reaches from 1600 m to 1800 m in the central part. It is generally thought (Pinto da Silva & Teles 1980, Batista 1982) that the upper reaches of the *Quercus pyrenaica* forests were at these altitudes, but this is difficult to visualize in the field due to the extreme scarcity of trees in the central part of the mountain. The only occurrences of trees are some few *Quercus pyrenaica* shrub-like trees in crevices of inaccessible rocks and a single *Ilex aquifolium* shrub at 1800 m. *Salix* shrubs are occasionally found along streams. Degradation stages include *Erica arborea* and *E. australis* heathlands, *Erica australis* and *Juniperus communis* heathlands, *Nardus stricta* grasslands, *Erica umbellata* and *Halimium alyssoides* heathlands, and open vegetation (Arenario-Cerastietum ramosissimi; Pinto da Silva & Teles 1980). The upper, sub-alpine zone reaches from 1800 m to 2000 m altitude. There are no records of tree species. The vegetation is heavily grazed; degradation stages include open *Juniperus communis* scrub, *Nardus stricta* grasslands, and open grasslands belonging to the Arenario-Cerastietum with towards the summit increasing amounts of *Plantago penyalarensis*. Other shrub species are present but scarce (*Erica*, *Calluna*, *Genista*, *Cytisus*, *Halimium*).

Site description

The Vale da Candeeira is a hanging valley opening into the upper valley of Rio Zêzere (one of the main streams of the Serra da Estrêla, and tributary to Rio Tejo further south) 7 km south of the village of Manteigas, 4 km north-east of the highest summit (Torre). The permanent stream of Ribeiro da Candeeira runs through the valley and drops into the Zêzere valley with a cascade which is spectacular only during snowmelt in early spring. At 1400 m altitude, just behind the entrance of the Candeeira valley and a few hundred metres from the Zêzere valley lies the study site of Charco da Candeeira, a small circular former lake of 100 m diameter approximately. The lake is now filled-up with sediments; it is now a pond with half a metre of water in winter, but in summer it is completely dry. The surface is densely overgrown with *Ranunculus* subgenus *Batrachium*, *Juncus heterophyllus* and the floating grass *Antinoria agrostidea* ssp. *natans*. In the wet marginal area, scattered *Carex nigra* and large hummocks of

Carex nigra, *Juncus effusus* and *Molinia coerulea* are abundant, in which *Wahlenbergia hederacea* is occasionally found. A moist peaty area about half the size of the pond is present at the south-western corner of the pond. It is dominated by *Nardus stricta*; some additional species are *Carex nigra*, *?Agrostis capillaris?*, *Narcissus bulbocodium*, *Galium hercynicum*, and *Potentilla erecta*. *Viola palustris*, although absent here, is typical for this vegetation type. The dry areas in the direct surroundings of the pond and on greater part of the valley floor are heavily grazed and are dominated by open grassland communities which are intermediate between Tuberarietalia-guttatae communities rich in annual species typical for acid soils in the Iberian lowlands (Rivas-Martinez 1977) and the Arenario-Cerastietum ramosissimi rich in perennial herbs typical for the high plateau of the Serra da Estrêla above ca. 1600 m (Braun-Blanquet et al. 1952, Pinto da Silva 1980). Rock-roses (*Halimium alyssoides*) occur in these grasslands. The slopes are for the greater part covered with scrub of brooms (*Genista*, *Cytisus*), *Erica arborea*, *E. australis*, *E. umbellata*, *Calluna* and *Juniperus communis*. These scrubs are subject to frequent burning by the shepherds for improvement of the grazing areas. A few isolated *Quercus pyrenaica* and *Ilex aquifolium* trees and, according to Batista (1982), also one *Taxus baccata* tree are found on the inaccessible, steep, rocky, south-exposed slope where they are protected against grazing and burning. An annotated list of vascular-plant species encountered in the Vale da Candeeira is presented in table I.

Field methods

Preliminary corings were made on 18-19 August 1983 with a Dachnowsky corer. The section used was cored on 18 and 19 August 1985 by Prof. Dr. C. Roel Janssen (sport shoes, bandage on left ankle, greasy white breeches, blue cap, beige short-sleeved shirt), Ton van Druten (dirty Texas T-shirt, peasant handkerchief around neck, blue breeches, red cap), Hans Joosten (green blouse and naked belly, white cap, dirty blue jeans, boots), Ine Joosten, Torbjörn Törnqvist (beige tattered dirty trousers, no blouse and naked belly, sport shoes, blue cap), Peter Hoen (blue jeans, light blue-red-white blouse, mountain shoes, blue cap), Hanneke Bos, Marlies Marbus (always clean), Henk van Stiphout and Mieke Caris (filming duo). The 'Parque Natural da Serra da Estrêla' (an institution for the conservancy of nature and landscape in the Serra da Estrêla) was helpful with the transport of the equipment in the field. The transport was carried out with donkeys hired from a local farmer; thanks to god the farmer himself was so kind to handle the donkeys. The coring site was in the middle of the then completely dry pond, where the sediment was thickest (prospection with gouge). The coring was carried out with a Livingstone corer with a diameter of 8 cm and a length of 108 cm. Total length of the section is 14 m; the material came out in 16 cores. An additional section of the upper 40 cm named SDC-A-17 was taken with a spade on 16-6-1990 by the authors from a living *Molinia* tussock at the margin of the pond some tens of metres south-east of the original coring site. The top of lake sediment in the *Molinia* tussock was elevated ca. 15 cm above the near surroundings; for measuring purposes, this level is regarded as 0 cm.

The flora of the Serra da Estrêla was studied in the years 1987-1990, with special attention for the ecology of vegetation types and of individual plant species. About one thousand plants were collected, many of which were used for the enlargement of the pollen-reference collection in the Laboratory of Palaeobotany and Palynology (Utrecht).

Lithology

-25 cm to -6 cm: basal parts of the *Molinia* plants forming the tussock (leave sheaths, culms and nodes, roots), containing small quantities of decayed material.

- 6 cm to 0 cm: as above, but containing more decayed material.

(cm to 175 cm: rather dry, decayed, crunchy detritus gyttya, in the *Molinia* tussock mixed with living roots. This type of deposit is in the Serra da Estrêla characteristic for ponds (with water in winter, dry in summer).

5 to 952 cm: wet, soft, black gyttya. This type of deposit is in the Serra da Estrêla characteristic for lakes (with water all the year round).

952 to ca. 1205 cm: laminated mixtures of wet, soft, black gyttya and white silt; specific-weight values are a relative measure for the amount of silt.

Ca. 1205 to 1400 cm: soft, pure white silt.

Pollen morphology

For the identification of pollen and spores were used the Northwest European Pollen Flora parts I to V ('NEPF'), the enormous reference collection of the Laboratory of Palaeobotany and Palynology (Utrecht), and personal assistance of Dr. W. Punt (Utrecht). Advise on pollen morphology within the families Ericaceae and Cistaceae was provided by José Mateus and Paula Queiroz, respectively. All pollen and spore types representing a taxonomic unit have the name of that unit (e.g., Cyperaceae, *Quercus*, *Scleranthus annuus*). Such names have the extension 'total' if they represent the sum of more narrow-defined types (e.g., Umbelliferae total includes all types distinguished within this family). Names of other types have the extension 'type', 'indet.' or 'subtotal'. Names with the extension 'type' include more taxa than the name represents (e.g., *Anthemis* type includes the species of *Anthemis* and a few other genera); these taxa taken together do not represent a single taxonomic unit. Names with the extension 'indet.' are family names and include grains which could not be allocated to one of the types distinguished inside that family (e.g., Umbelliferae indet.). Names with the extension 'subtotal' are family names and represent the sum of more or less similar types distinguished within that family, but excludes some very characteristic types (e.g., Compositae tubuliflorae subtotal represents the sum of all types distinguished within the Compositae tubuliflorae, except *Artemisia* and a few others). In Table II, all pollen types encountered are listed and comments are given.

Pollen diagrams

<u>Pollen sum</u>

The basis for calculation of pollen percentages for the Holocene part of the section (50 cm to top; Figs. 6 to 10) is a sum of selected pollen and spore types ('pollen sum') chosen in such a way that fluctuations in pollen and spore curves should reflect changes in vegetation <u>outside</u> the studied pond or lake ('regional' vegetation), but should be independent of changes in aquatic and marsh vegetation <u>inside</u> the pond or lake ('local' vegetation) (Ref.: wie kan ik hiervoor citeren?). The pollen sum includes therefore all pollen and spore types of plants not present at the site during the Holocene period. It includes also those marsh plants represented with consistently low or very low percentages: Cruciferae, *Epilobium*, *Equisetum*, *Galium*, *Menyanthes*, *Montia fontana*, *Parnassia*, *Pedicularis*, *Potentilla*, *Typha latifolia*, *Viola*. The pollen sum excludes all pollen and spore types which are (mainly) derived from aquatic plants (Gramineae (because of the aquatic grass *Antinoria agrostidea*), *Isoetes*, *Myriophyllum alterniflorum*, *Nymphaea*, *Potamogeton*, *Ranunculus* (mainly subgenus *Batrachium*), *Sparganium*) and from marsh plants present along the lake or pond in any period during the Holocene (*Betula*, Cyperaceae, *Dryopteris* type, Hepaticae, *Lythrum*, *Sphagnum*). The exclusion of *Betula* might need some explanation. A comparison of all pollen diagrams available from the Serra da Estrêla (van den Brink & Janssen 1 35, and many unpublished diagrams) suggests that *Betula* trees were present in small quantities only and nearly exclusively at the margins of lakes and ponds; it is therefore a marsh plant.

The pollen sum for the Late-Glacial part of the section (955 cm to base) excludes *Sphagnum* and Hepaticae spores and all aquatic pollen and spore types (*Myriophyllum alterniflorum*, *Potamogeton*, *Ranunculus*, *Sparganium*), but includes all other pollen and spore types of vascular plants.

Pollen diagrams and order of pollen types

The palynological results have been split up into six biostratigraphical subsections numbered A to F (Figs. 5 to 10) for practical purposes. Each subsection comprises a main period in the vegetation history.

Zonation

Zones are distinguished in the diagrams in order to facilitate the discussion of vegetation succession. Zone boundaries are chosen primary to mark events in the succession of regional vegetation. Each zone starts therefore with such an event. Sub-zones are distinguished to mark either short-lived or minor events in the regional vegetation succession, or to mark events in the succession of local vegetation (aquatic or marsh vegetation). As a result, the majority of events in the local vegetation succession are marked, too. Although this zonation procedure is based on between-zone differences, it has resulted in considerable within-zone homogeneity.

Principles of interpretation

The interpretation of the pollen diagrams depends on (a) the ecological conditions of the site and its surroundings, which are described in the chapter 'Description of site and surroundings' above, (b) production and dispersal properties of the pollen and spore types involved, and (c) the ecology and field distribution of the species. Our knowledge of these factors is mainly based on the study of the area as it is today: the present must be the key to the past. A main restriction is that these insights are mainly applicable in the Holocene period, since its flora and ecological conditions are thought to have been at least reasonably comparable with today's. They are, however, less applicable in the Late-Glacial period, since the flora of the latter is badly known (due to ambiguity in the relation of pollen types versus plant species) and the ecological conditions are thought to have been largely different from today's. (b) and (c) are discussed below.

Scales of interpretation

Dependent on the pollen type, the interpretation of trends in pollen curves refers to different scales in the landscape, because of differences in pollen production and pollen-dispersal properties of the various plant species (cf. Janssen 1976). The following account is based on (1) the results from combined pollen and vegetation studies in surface-sample transects in other middle-high mountain areas (Vosges in France: Janssen 1981; Monts du Forez in France: Lutgerink et al. 1989) and in the Serra da Estrêla (unpublished data), (2) the ecology and distribution of species in the Serra da Estrêla, and (3) trends in pollen curves in the diagrams. The scales distinguished are:

An extra-regional scale (a) comprises areas outside the Serra da Estrêla and its direct surroundings, more than tens of kms away. It concerns tree pollen *Corylus*, *Ulmus*, and shrub pollen *Ephedra* spp., *Hippophaë*. For many other types, isolated occurrences of grains are likely to be extra-regional; an example is *Olea*.

A regional scale comprises the area between a few kms to many tens of kms from the study site and concerns the interpretations based on upland-tree pollen and some shrub- and herb-pollen types. A subdivision of types based on the ecology and present-day distribution of species, but also on the trends in pollen curves, can be made between (b) lowland tree, shrub and herb pollen reflecting vegetation in the lower valleys from several kms up to a few tens of kms away (tree pollen *Pinus*, *Alnus*, *Fraxinus*, *Phillyrea*, *Olea*, *Juglans*, *Castanea*, *Frangula*, *Ilex*, *Cornus sanguinea*, *Prunus*, *Acer*, *Arbutus*, *Viburnum tinus*, *Rhamnus*, *Sambucus nigra*, shrub pollen *Pistacia*, *Vitis*, *Myrtus*, *Daphne* type, *Hedera*, herb pollen *Artemisia*), and (c) pollen from trees and spores from a single moss around the site and herb pollen from nearby valleys at lower altitudes (predominantly indicators of agriculture), reflecting mainly vegetation between a few and several kms away (tree pollen *Quercus*, *Taxus*, *Sorbus*, moss spores *Hedwigia*, herb pollen Chenopodiaceae type, *Plantago lanceolata* type, Cerealia, *Sanguisorba minor*, *Echium*, many other types represented with single grains).

An extra-local scale ranging from tens of metres to a few kms can be divided as follows: (d) Trends in pollen curves reflecting vegetation changes on a scale between hundreds and thousands of metres, including shrub and upland-herb pollen (shrub pollen *Salix* p.p., *E. arborea* type p.p., *E. australis* type, *E. umbellata*, *Calluna*, *Juniperus*, *Genista* type, *Sarothamnus*, *Halimium* type, and herb pollen *Rumex acetosella* type, *Pteridium*, *Asphodelus albus*, *Saxifraga* types, *Hypericum perforatum* type, Cruciferae, Gramineae p.p., Cyperaceae p.p., many types of the families of Compositae tubuliflorae, Umbelliferae, Compositae liguliflorae, Monocot bulbs, Caryophyllaceae, Papilionaceae and Campanulaceae); (e) A scale of tens to hundreds of metres is applicable to curves of pollen and spores from marsh plants (tree pollen *Betula*, *Salix* p.p., shrub pollen *E. arborea* type p.p., herb pollen and spores *Dryopteris* type, Gramineae p.p., Cyperaceae p.p., *Lythrum*, *Carum verticillatum*, *Galium* type, *Potentilla*, *Pedicularis*, moss spores Hepaticae and *Sphagnum*).

A local scale concerning the vegetation in the lake or pond itself concerns the interpretations based on (f) pollen from aquatic and semi-aquatic plants (*Sparganium*, *Potamogeton*, *Nymphaea*, *Ranunculus* (subg. *Batrachium*), Gramineae p.p. (i.c. *Antinoria*), periodically submerged Cyperaceae p.p. (i.c. *Carex nigra* p.p.)).

It must be remembered that the interpretation of single pollen types can not strictly be confined to the categories to which they are allocated above, since in many cases different parts of a single curve can be be recognized to be local, extra-local, or regional.

Ecological factors and ecology of species

Due to drastic changes in vegetation and landscape in the second half of the Holocene period as a result of ever-increasing and ever-changing human impact, only part of the ecological factors determining the vegetation development during the Holocene are still relevant today and could be studied in the field; other ecological factors had to be inferred from the diagrams. The ecological factors will be discussed here in the chronological order in which they have become important in the Holocene. In order to facilitate the interpretation of the diagram, the ecology of species will be added in simplified form, i.e. as indicative values of pollen and spore types.

Autogenous succession. Vegetation succession not influenced by climatic fluctuations or human interference is recognized in the diagram only in the development of the forests directly after the climatic warming-up at the beginning of the Holocene. It is reflected in the rise of *Quercus* pollen and the decline of many herb-pollen types (*Rumex acetosella* type, *Plantago alpina* type *Botrychium*, *Echium*, several Umbelliferae types).

Climatic fluctuations. The effect of climatic fluctuations on vegetation can be recognized only in periods before the dominance of human interference. The Late-Glacial is a classic example. An example in the Holocene is the period after the development of forests at the beginning of the Holocene and before the start of stronger human interference some thousands of years later. Changes towards more oceanic conditions are indicated by (slight) declines of *Quercus* pollen together with (slight) rises of *Pinus* pollen, in many cases coinciding with rises of *Erica arborea* type, *Alnus*, *Pteridium*, *Taxus*, *Genista* type or *Sarothamnus* pollen. Changes towards more continental conditions are indicated by (slight) rises of *Quercus* pollen coinciding with (slight) declines of *Pinus* pollen.

Human activities inside the forests. The first human interference to be recognized are local, small-scale human activities in the forests (possibly grazing). They are indicated by slight declines of *Quercus*, *Pinus*, *Taxus* pollen and non-synchronous rises of *Ilex*, *Erica aborea* type and other shrub and herb pollen types indicating activities at different scales and distances.

Grazing. Increased grazing is indicated by (a) declines of *Quercus* and *Pinus* pollen indicating reduction of forests, (b) declines of *Taxus* pollen, rises of shrub pollen (*Sorbus*, *Erica* types, *Genista* type, *Sarothamnus*) and various herb pollen types of plants of dry soils (*Sedum* type, *Rumex acetosella* type, *Daucus*, *Peucedanum* type, and others), and (c) rises of Gramineae and *Ranunculus* pollen, derived from marsh plants and aquatics and indicative of eutrophication of the lake or pond.

Cultivation of arable fields. Indicated by rises of Cerealia and Chenopodiaceae type pollen and declines of pollen of marsh plants and aquatics indicative for eutrophication of the lake or pond.

Degradation and regeneration of forests. Forest degradation is indicated by declines of *Pinus* and *Quercus* pollen, regeneration by rises of *Quercus* pollen.

Cultivation of woody nutrient plants. Indicated by rises of *Vitis*, *Olea* and *Castanea* pollen.

Over-grazing. Indicated by rises of *Merendera*, *Paronychia polygonifolia* type and *Arenaria* pollen.

Deforestation. Indicated by a decline of *Quercus*, *Betula* and *Pinus* pollen and a rise of *Erica arborea* type pollen.

Plantation of trees. Indicated by a rise of *Pinus* and *Eucalyptus* pollen.

Degradation of heathlands. Indicated by a decline of *Erica arborea* pollen.

Soil erosion. Indicated by a decline of many herb pollen types: *Pteridium*, *Asphodelus albus*, Compositae tubuliflorae (*Aster* type, *Anthemis* type, *Senecio*), Compositae liguliflorae, *Jasione* type, *Armeria*, *Centaurea nigra* type, Monocot bulbs (*Narcissus pseudonarcissus* type, *Ornithogalum* type, *Veratrum*), Umbelliferae (*Chaerophyllum temulentum*, *Daucus*, *Peucedanum* type, *Physospermum*, *Pimpinella saxifraga* type), *Galium* type, *Potentilla*, *Genista* type, *Sedum* type, and by a rise of *Halimium* type pollen.

Lithology

Specific weights reflect directly the proportions of the organic component (very low s.w.) and silt (high s.w.). It is thought that the silt has been blown-in or washed-in during periods of erosion and little vegetation in the surroundings. Specific weights are therefore used as a relative measure for erosion and the quantity of vegetation in the catchment area.

Extensive summary of interpretation

A. Late-Glacial

Climate-induced successions from polar desert to savannah and back to steppe, under cool and dry, continental climatic conditions.

Zone A1: Bølling. Some trees in sheltered nooks at the foot of the mountains, but polar desert (no vegetation) around the site, indicating a cold and dry climate.

Zone A2: Succession around the site from polar desert to steppe vegetation, indicating a climatic amelioration.

Subzone A3a: Older Dryas. Some expansion of trees at lower altitudes and expansion of marsh vegetation around the site, indicating increased precipitation.

Subzone A3b: Short period of relatively dense shrub vegetation around the site, possibly as a response to renewed climatic change.

Subzone A4a: Allerød. Some expansion of *Quercus* at lower altitudes and a succession from steppe to savannah around the site, indicating markedly increased temperatures.

Subzone A4b: Increase of *Betula* around the site, indicating increased precipitation.

Subzone A4c: Closing of *Betula* thickets and formation of peat around the site, explained by autogeneous succession.

Subzone A4d: Minor decline of *Quercus*, indicating a minor cooling.

Subzone A4e: Paludification around the lake.

Subzone A4f: Short-term *Quercus* maximum in the lowlands, indicating a short-term temperature maximum.

Subzone A5a: Younger Dryas. Decrease of trees both in the lowlands and around the site and expansion of grass vegetation around the site, indicating a marked cooling.

Subzone A5b: Increase of vegetation on inorganic soils, indicating soil erosion.

Subzone A5c: Replacement of shrubs by herbs around the site, suggesting increased grazing by large wild herbivores.

Subzone A6a: Decline of *Quercus* in the lowlands, indicating a marked cooling.

Subzone A6b: Succession from savannah to steppe around the site, indicating a cooler and drier climate, but also suggesting increased grazing by large wild herbivores.

Subzone A6c: Expansion of grassland vegetation, suggesting increased grazing by large wild herbivores.

Zone A7: Increase of *Quercus* in the lowlands and development of herb-rich shrublands around the site, indicating slightly rising temperatures.

Holocene:

B. Development of xerothermic forests

Succession from steppe to forest under warm and rather dry climatic conditions and without interference of man.

Zone B1: Rapid succession around the site from steppe to savannah, indicating strongly increased temperatures.

Zone B2: Rapid succession around the site from savannah to forest, as a result of the earlier increase of temperatures (Zone B1).

Subzone B2b: Temporary *Quercus* minimum and establishment of *Taxus*, suggesting increased precipitation.

Zone B3: Final closing of the forest with a dominant role of *Quercus* and a minor role of *Pinus*, probably as a result of autogeneous succession towards its climatic climax, suggesting a warm and rather dry climate.

Zone B4: Decline of shrubs and establishment or increase of many herbs, indicating both autogeneous succession and slightly increased precipitation.

Subzone B4b: Paludification around the lake and slight increase of Cerealia-type grains, the latter probably derived from wild grasses.

C. Climate-induced forest dynamics

Forests; climate turns moister and cooler and is the main factor determining the forest dynamics. The anthropogenic factor starts to play a minor but increasing role.

Zones C1 to C3: Succession from xerothermic to mesothermic forests.

Zone C1: Marked decline of *Quercus* and increase of *Pinus* and several other species, indicating increased precipitation.

Zone C2: Marked decline of *Quercus* and increase of *Pinus* and several other species, indicating increased precipitation.

Zone C3: Marked decline of *Quercus* and increase of *Pinus* and several other species, indicating increased precipitation.

Subzone C4a: A combination of various small vegetation changes, indicating a first, minor human influence on the forests.

(Sub)Zones C4b to C10: Stable forest vegetation with minor climatically and human-induced successions.

Subzone C4b: Increase of *Quercus* and decline of *Pinus*, indicating decreased precipitation.

Zone C5: Decline of *Quercus* and increase of *Pinus* and several other species, indicating increased precipitation and possibly increased grazing.

Zone C6: Increase of *Quercus* and decline of *Pinus*, indicating decreased precipitation; increase of herbs and shrubs nearby the site, indicating increased grazing.

Zone C7: Decline of *Quercus* and increase of *Pinus* and several other species, indicating increased precipitation and increased grazing.

Subzone C7b: Decline of Cerealia.

Zone C8: Increase of *Quercus* and decline of *Pinus*, indicating decreased precipitation.

Zone C9: Decline of *Quercus* and increase of *Pinus* and several other species, indicating increased precipitation.

Zone C10: Slight increase of *Quercus* and decline of *Pinus* and *Pteridium*, indicating slightly decreased precipitation; paludification of vegetation around the lake; changes in aquatic vegetation, suggesting lake-level change; slight increase of Cerealia and some other species, indicating somewhat increased human activity.

D. Anthropogenic forest dynamics

The area covered by forests is hardly affected by man, but the forest dynamics as read from the diagram are predominantly human-induced: there is some grazing in the forests and there are small-scale local deforestations.

Zone D1: Marked decline of trees and increase of shrubs, indicating the first anthropogenic deforestation; succession of aquatic vegetation towards Fontinalo-Ranunculetum, indicating eutrophication of the lake through local grazing.

Zone D2: Various vegetation successions at different scales, indicating scattered human activities.

Zone D3: Forest regeneration, increase of species indicating grazing, decline of species indicating cultivation of fields, together suggesting instability of human society.

Zone D4: Some deforestation; eutrophication of lake vegetation, indicating increased grazing; increase of *Merendera* and decline of many species, indicating over-grazing.

Zone D5: Increase of vegetation around the site and decrease of eutrophication of the lake, indicating reduced over-grazing.

Zone D6: Forest regeneration and increase of *Sphagnum* around the lake, indicating decreased grazing; increase of Cerealia and weeds, indicating expansion of fields.

Zone D7: Various vegetation successions at different scales, indicating scattered human activities including increased grazing.

E. Semi-deforested cultural landscape

Large-scale deforestations take place, but the forests retain their capacity to regenerate. Deforestation phases, stable phases and forest-regeneration phases succeed each other, in relation to changing patterns and intensity of human pressure.

Zone transition D7-E1: Transition from lake to pond.

Zone E1: Strong decline of trees, increase of shrubs and herbs and eutrophication of pond vegetation, indicating deforestation through grazing. Decline of Cerealia and hay-field herbs, indicating abandonment of fields.

Zone transition E1-E2: Strong decline of trees and increase of some herbs, indicating progressing deforestation and increased grazing.

Zone E2: Rather stable forest vegetation, indicating stable activity patterns; decrease of eutrophication of pond, indicating local decrease of grazing.

Zone E3: Strong decline of trees and increase of shrubs and herbs, indicating progressing deforestation through grazing and possibly over-grazing.

Zone transition E3-E4: Strong deforestation and increase of herbs, indicating increased grazing; increase of *Vitis* and *Olea*, indicating increased Roman activity at lower altitudes.

Zones E4-E5: Period of maximum deforestation, indicating continuous high human activity.

Subzone E5a: Start of *Castanea*, indicating chestnut cultivation by Romans; changes in herb vegetation around the site, indicating some reduction of (the still strong) grazing.

Subzone E5b: Eutrophication of pond vegetation, indicating increase of local grazing.

Subzone E5c: Development of *Betula* swamp forest adjacent to the pond, indicating locally diminished grazing.

Subzone E5d: Marked *Pinus* decline, indicating deforestation at lower altitudes, possibly through burning.

Zone E6: Partial forest regeneration, indicating reduced human activity.

Zone E7: Short-span deforestation, as a result of human influence.

Subzone E8a: Forest regeneration, indicating reduced human activity.

Subzone E8b: Moderate deforestation and increase of some herbs, indicating increased grazing.

Zone E9: Stable forests, indicating unchanged human activity in the mountains; decline of lowland shrubs, indicating increased human activity in the lowlands, as a forebode of the forest destruction soon to follow.

F. Anthropogenic forest destruction and landscape degradation

Anthropogenic pressure increases to such an extent that the forests virtually disappear and organic soils are for the greater part eroded and flushed away. The main agents are grazing, burning, agriculture and large-scale plantation of pines.

Large-scale deforestation:

Zone F1: Strong decline of *Quercus* and many herbs, increase of *Erica arborea* and eutrophication of the pond, indicating large-scale deforestation and over-grazing.

Subzone F2a: Strong decline of *Quercus* and many herbs and increase of *Halimium*, indicating progressing large-scale deforestation and erosion.

Subzone F2b: Strong decline of *Quercus* to low values and maximum of *Erica arborea*, indicating completed deforestation; increase of *Olea* and some herbs, indicating humanactivity at lower altitudes.

Landscape degradation:

Zone F3: Minor increase of *Pinus*, indicating the first plantation of pines; strong decline of *Erica arborea* and increase of several shrubs, indicating strong soil erosion (leading to irreversible landscape degradation).

Subzone F4a: Very strong increase of *Pinus*, indicating large-scale pine plantation; decline of *Erica arborea*, indicating progressing soil erosion.

Subzone F4b: Very strong increase of *Pinus* and appearance of additional exotic trees, indicating large-scale plantation of pines and other exotics; decline of *Erica arborea*, indicating progressing soil erosion.

Zone F5: Strong increase of *Pinus* and decline of forest trees, indicating large-scale pine plantation; decline of *Erica arborea*, indicating progressing soil erosion; decline of Cerealia, indicating abandonment of rye fields in the mountains.

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Table I.

Species encountered in the Vale da Candeeira between 1400 m and 1450 m by W.O. van der Knaap and J.F.N. van Leeuwen in 1987, 1988 and 1989. Nomenclature follows Franco (1971, 1984) for the dicotyledons and the Flora Europaea V for the monocotyledons.

Quantities:
- r rare
- o occasional
- f frequent
- a abundant
- d dominant
- C only in the pond of Charco da Candeeira (addition to o, f, a or d)
- l locally (addition to f, a, d or C)
- \- not encoutered as pollen type

Aquifoliaceae:
r *Ilex aquifolium*

Boraginaceae:
o *Myosotis discolor*

Campanulaceae:
f *Campanula lusitanica*
f *Jasione* cf. *montana*
lf *Wahlenbergia hederacea*

Caryophyllaceae:
f *Arenaria aggregata*
o *Arenaria montana*
f *Cerastium gracile*
f *Cerastium pumilum*
o- *Corrigiola litoralis*
o *Dianthus laricifolius*
o *Dianthus lusitanicus*
o *Herniaria scabrida*
r- *Moenchia erecta* ssp. *erecta*
o *Paronychia polygonifolia*
o *Petrorhagia nanteuilii*
o *Scleranthus annuus*
r *Silene nutans*
o *Silene alba* ssp. *divaricata*
r *Silene vulgaris*
o *Silene foetida*
a *Spergula morisonii*
f *Spergularia* spec.
o *Stellaria graminea*

Cistaceae:
f *Halimium alyssoides*
o *Tuberaria guttata*

Compositae liguliflorae:
a *Arnoseris minima*
f *Hieracium castellanum*
f *Hypochoeris glabra*
o *Hypochoeris radicata*
r *Lactuca viminea*

Compositae tubuliflorae:
o *Anthemis arvensis*
o *Carduus carpetanus*
o *Centaurea coutinhoi*
r *Cirsium palustre*
f *Filago minima*
o *Phalacrocarpum oppositifolium*
o *Senecio vulgaris*

Crassulaceae:
f *Sedum arenarium*
f *Sedum brevifolium*
o *Sedum hirsutum*
o *Umbilicus rupestris*

Cruciferae:
o *Rhynchosinapis pseuderucastrum* ssp. *orophila*
f *Teesdalia nudicaulis*

Cupressaceae:
f *Juniperus communis*

Cyperaceae:
o *Carex laevigata*
Co *Carex nigra*
o *Carex ovalis*

Droseraceae:
r *Drosera rotundifolia*

Ericaceae:
f *Calluna vulgaris*
f *Erica arborea*
f *Erica australis*
f *Erica umbellata*

Fagaceae:
r *Quercus pyrenaica*

Filicales:
r *Asplenium billotii*

f *Pteridium aquilinum*

Geraniaceae:
o- *Erodium cicutarium*

Gramineae:
f *Agrostis capillaris*
a *Agrostis delicatula*
f *Aira praecox*
f *Anthoxanthum aristatum*
Cf *Antinoria agrostidea*
o *Arrhenatherum album*
o *Avenula sulcata* ssp. *marginata*
f *Corynephorus canescens*
o *Festuca elegans*
f *Festuca 'duriuscula'*
f *Festuca rubra*
o *Holcus mollis*
a *Micropyrum tenellum*
a *Molineriella laevis*
Co *Molinia coerulea*
a *Nardus stricta*
f *Poa bulbosa*
f *Stipa gigantea*
r *Trisetum hispidum*
a *Trisetum ovatum*

Guttiferae:
o *Hypericum humifusum*
? *Hypericum linifolium*

Juncaceae (-):
r *Juncus bulbosus*
Co *Juncus effusus*
Cf *Juncus heterophyllus*
r *Juncus tenageia*
r *Luzula caespitosa*
r *Luzula lactea*

Labiatae:
r *Ajuga pyramidalis ssp. meonantha*
o *Teucrium salviastrum*

Monocot bulbs
(Liliaceae - Iridaceae - Amaryllidaceae):
o *Allium sphaerocephalon*
r *Asphodelus albus* (sterile)
o *Fritillaria lusitanica*
a *Gagea nevadensis*
o *Hyacinthoides non-scripta*
f *Merendera pyrenaica*
Co *Narcissus bulbocodium*
f *Narcissus rupicola*
o *Ornithogalum concinnum*

Linaceae:
o *Radiola linoides*

Onagraceae:
r *Epilobium cf. obscurum*

Papaveraceae:
o- *Corydalis claviculata*

Papilionaceae:
r *Adenocarpus hispanicus*
o *Cytisus grandiflorus*
o *Cytisus multiflorus*
o *Cytisus purgans*
f *Cytisus striatus*
r *Echinospartum lusitanicum*
f *Genista anglica*
o *Genista cinerea*
a *Genista florida*
o *Lotus corniculatus*
f *Ornithopus perpusillus*
o *Trifolium repens*
o *Vicia sativa*

Plantaginaceae:
o *Plantago penyalarensis*

Plumbaginaceae:
r *Armeria carpetana*

Polygalaceae:
o *Polygala serpyllifolia*

Polygonaceae:
a *Rumex angiocarpus* (=*acetosella* s.l.)

Portulacaceae:
f *Montia fontana* ssp. *amporitana*

Ranunculaceae:
f *Ranunculus bulbosus*
f *Ranunculus ollissiponensis*
o *Ranunculus henriquesii*
f *Ranunculus nigrescens*
la *Ranunculus* subgenus *Batrachium* (only in water)

Resedaceae:
o *Sesamoides canescens*

Rosaceae:
o *Potentilla erecta*
o *Rubus* spec. (not *ulmifolius*)
o *Sorbus aucuparia*

Rubiaceae:
r *Crucianella angustifolia*
r *Galium helodes*
f *Galium hercynicum*
r *Galium verum*

Saxifragaceae:
o *Saxifraga granulata*
o *Saxifraga spathularis*

Scrophulariaceae:
o- *Digitalis purpurea*
f *Veronica arvensis*

Taxaceae:
r *Taxus baccata* at 1550 m (according to Batista, 1982)

Umbelliferae:
r *Angelica laevis* (sterile)
f *Conopodium majus*

Urticeae:
r *Urtica dioica*

Violaceae:
f *Viola langeana*

Table II

All pollen types encountered are listed and ordered on family. Family names not used in the name of a pollen type are bracketed. As far as is possible with the present state of knowledge of pollen morphology, the taxa included in types with the extension 'type' or 'subtotal' are listed according to the present-day flora of the area. Trees and shrubs are indicated as such. The separation between the two is somewhat arteficial; high shrubs (like *Corylus*) are listed as trees.

(Aceraceae:)
Acer (tree).
(Anacardiaceae:)
Pistacia (shrub).
(Aquifoliaceae:)
Ilex (only *I. aquifolia*) (tree).
(Araliaceae:)
Hedera (only *H. helix*) (shrub).
(Boraginaceae:)
Echium
Pentaglottis (only *P. sempervirens*).
(Campanulaceae:)
Campanula
Jasione type: includes *Wahlenbergia*.
(Caprifoliaceae:)
Lonicera periclymenum (shrub)
Sambucus nigra (tree)
Viburnum tinus (tree).
(Caryophyllaceae: pollen morphology insufficiently known, but all regional species were studied)
Caryophyllaceae subtotal: includes subfamilies Alsinoideae and Silenoideae, but excludes Paronychioideae, and is the sum of the following types:
Arenaria (in the area only *A. aggregata* and *A. montana*)
Caryophyllaceae indet.
Cerastium
Dianthus lusitanicus type: includes also *D. laricifolius* and *Petrorhagia*
Lychnis type: includes also *Silene elegans*
Melandrium: includes *Silene dioica* and *S. pratensis*
Minuartia (in the area only *M. recurva*)
Sagina
Scleranthus annuus
Silene foetida type: includes also *S. macrorhiza* and *S. nutans*
Silene vulgaris type: includes several *Silene* and *Dianthus* species
Stellaria

(Paronychioideae:)
Herniaria type: includes also *Illecebrum*
Paronychia polygonifolia type: includes also *P. argentea*
Spergula
Spergularia type: includes also *Polycarpon tetraphyllum*.
Chenopodiaceae type: includes also Amaranthaceae.
(Cistaceae:)
Halimium type: includes also *Tuberaria* and *Cistus* except for *C. ladanifer* and *C. populifolius* (shrub)
Helianthemum type
Cistus ladanifer type: includes also *C. populifolius* (shrub).
(Compositae: pollen morphology insufficiently known, but many regional species were studied)
Ambrosia
Anthemis type: includes also *Phalacrocarpum*
Anthemis-small type: plant taxa unknown
Artemisia
Aster type: includes also *Anaphalis*, *Antennaria*, *Helichrysum*
Bellis type
Centaurea nigra type: includes *C. coutinhoi* and some other *Centaurea* species
Centaurea scabiosa type: includes several other *Centaurea* species
Cirsium type: includes also *Carduus*
Compositae liguliflorae
Compositae tubuliflorae ind.
Compositae tubuliflorae subtotal: includes subfamily Asteroideae with exception of *Ambrosia*, *Artemisia*, *Centaurea nigra* type, *C. scabiosa* type
Filago type: includes *Filago* s.l. and also *Gnaphalium*
Jurinea
Senecio
Solidago.
(Cornaceae:)
Cornus sanguinea (tree).
(Corylaceae:)
Alnus (tree)
Betula (tree)
Corylus (tree).
(Crassulaceae:)
Sedum type: includes also *Umbilicus*.
Cruciferae.
(Cupressaceae:)
Juniperus (shrub).
(Cuscutaceae:)
Cuscuta.
Cyperaceae.
(Dipsacaceae:)
Succisa.
(Eleachnaceae:)
Hippophaë (genus unknown in Portugal) (shrub).
(Ephedraceae:)
Ephedra distachya type (shrub)
Ephedra fragilis type (shrub).
(Ericaceae:)
Arbutus (only *A. unedo*) (tree)
Calluna (only *C. vulgaris*) (shrub)
Erica arborea type: includes also *E. scoparia* and *E. lusitanica* (shrub)
Erica australis (shrub)
Erica umbellata (shrub).

(Euphorbiaceae:)
Mercurialis.
(Fagaceae:)
Castanea (only *C. sativa*) (tree)
Fagus (genus unknown in Portugal) (tree)
Quercus (tree).
(Filicales:)
Anogramma (only *A. leptophylla*)
Botrychium (only *B. lunaria*)
Dryopteris type: includes all smooth monolete spores (*Asplenium*, *Athyrium*, *Blechnum*, *Cystopteris*, *Dryopteris*, *Polystichum*, and others)
Equisetum
Isoetes
Polypodium
Pteridium (only *P. aquilinum*).
(Gentianaceae:)
Centaurium
Gentiana lutea/pneumonanthe
Gentianella.
(Geraniaceae:)
Geranium.
Gramineae: excludes Cerealia
Cerealia.
(Guttiferae: types according to NEPF)
Hypericum perforatum type: includes also *H. humifusum*, *H. linifolium*, and others.
(Haloragaceae:)
Myriophyllum alterniflorum
Hepaticae (= liverworts).
(Juglandaceae:)
Juglans (tree).
(Labiatae:)
Labiatae indet.
Lamium type: includes also *Galeobdolon*
Lavandula type: includes also *Mentha*, and other genera (shrub)
Stachys type
Teucrium type: includes also *Ajuga*.
(Linaceae:)
Linum
Radiola (only *R. linoides*).
(Lythraceae:)
Lythrum (including the former genus *Peplis*).
(Menyanthaceae:)
Menyanthes (only *M. trifoliata*)
Monocot bulbs: includes families Amaryllidaceae, Iridaceae, Liliaceae
Allium
Asphodelus albus
Fritillaria (only *F. lusitanica*)
Gagea (in the Serra da Estrêla only *G. nevadensis*)
Merendera (only *M. pyrenaica*)
Narcissus bulbocodium
Narcissus pseudonarcissus type: includes also *N. rupicola*, *N.triandrus*, *N. asturiensis*
Ornithogalum type: includes also *Scilla* (= *Hyacinthoides*)
Veratrum (only *V. album*).
(Musci:)
Hedwigia
Sphagnum.

(Myricaceae:)
Myrica (shrub).
(Myrtaceae:)
Eucalyptus (genus unknown in Europe) (tree)
Myrtus (only *M. communis*) (shrub).
(Nymphaeaceae:)
Nymphaea
(Oleaceae:)
Fraxinus (only *F. angustifolia*) (tree)
Olea (only *O. europaea*) (tree)
Phillyrea (tree).
(Onagraceae:)
Epilobium.
(Papaveraceae: types according to NEPF)
Papaver rhoeas type.
(Papilionaceae:)
Genista type: includes also *Chamaespartium*, *Cytisus*, *Echinospartum* (shrub)
Lathyrus
Lotus
Medicago
Ornithopus
Papilionaceae indet.
Sarothamnus (in the area *S. grandiflorus*) (shrub)
Trifolium
Ulex (shrub)
Vicia.
(Parnassiaceae:)
Parnassia (genus unknown in Portugal).
(Pinaceae:)
Picea (genus unknown in Portugal) (tree)
Pinus (tree).
(Plantaginaceae: types according to NEPF; pollen morphology of Portuguese species insufficiently known)
Plantago alpina type: includes *P. penyalarensis*
Plantago coronopus type: includes probably only *P. coronopus* s.s.
Plantago lanceolata type
Plantago major type.
(Plumbaginaceae:)
Armeria.
(Polygonaceae: types according to NEPF; pollen morphology of Portuguese species insufficiently known)
Polygonum aviculare type: includes also *P. arenastrum*, *P. maritimum*, *P. patulum*, *P. rurivagum*
Polygonum convolvulus type: includes also *P. dumetorum*
Rumex acetosella type: includes *R. angiocarpus* (the micro-species of *R. acetosella* s.l. in Portugal), *R. acetosa*, *R. induratus*
Rumex obtusifolius type: includes also *R. crispus*, *R. suffruticosus*.
(Portulacaceae:)
Montia fontana.
(Potamogetonaceae:)
Potamogeton.
(Primulaceae:)
Anagallis
Lysimachia.
(Ranunculaceae:)
Aconitum (only *A. napellus*)
Ranunculus (mainly subgenus *Batrachium*)
Thalictrum.

(Resedaceae:)
  Reseda type: includes also *Sesamoides*.
(Rhamnaceae:)
  Frangula (only *F. alnus*) (tree)
  Rhamnus (shrub).
(Rosaceae:)
  Alchemilla
  Filipendula
  Prunus (tree)
  Potentilla
  Rosaceae indet.
  Rubus (shrub)
  Sanguisorba minor
  Sanguisorba officinalis type (species unknown in Portugal)
  Sorbus (tree).
(Rubiaceae:)
  Galium type: includes also *Crucianella*.
(Salicaceae:)
  Salix (tree).
(Saxifragaceae: types according to NEPF)
  Saxifraga granulata type: includes also *S. tridactylites*
  Saxifraga stellaris type: includes also *S. clusii*, *S. continentalis*, *S. spathularis*.
(Scrophulariaceae:)
  Linaria
  Pedicularis
  Rhinanthus type: includes also *Veronica*
  Scrophulariaceae indet.
(Solanaceae:)
  Solanum dulcamara
  Solanum nigrum.
(Sparganiaceae:)
  Sparganium.
(Taxaceae:)
  Taxus (only *T. baccata*) (tree).
(Thymelaeaceae:)
  Daphne type: includes *Thymelaea* (genus not recorded from the area) (shrub).
(Typhaceae:)
  Typha latifolia.
(Ulmaceae:)
  Ulmus (tree).
Umbelliferae total (identification of types according to NEPF):
  Ammi (in Portugal only *A. visnagea*)
  Angelica archangelica type (species in Portugal unknown)
  Angelica palustris type (species in Portugal unknown)
  Angelica sylvestris (subdivision of *Peucedanum* type) includes *A. laevis*?
  Anthriscus sylvestris
  Apium nodiflorum
  Astrantia
  Berula erecta (renamed from *Sium latifolium* type; the latter unknown in Portugal)
  Bupleurum
  Carum verticillatum
  Chaerophyllum temulentum
  Cicuta (genus in Portugal unknown)
  Conium (only *C. maculatum*)
  Daucus
  Eryngium
  Heracleum (only *H. sphondylium*)
  Hydrocotyle (only *H. vulgaris*)

Laserpitium
Meum type: includes also *Ligusticum* (both genera in Portugal unknown)
Oenanthe
Peucedanum type: includes also *Foeniculum vulgare*, *Petroselinum crispum*, and a number of narrower-defined types when they could not be separated (*Angelica sylvestris*, *Selinum carvifolia*)
Physospermum (only *P. cornubiense*; renamed from *Pleurospermum austriacum* type; the latter unknown in Portugal)
Pimpinella anisum which type includes P. villosa?
P. saxifraga type: includes *P. major* (both species in Portugal unknown)
Selinum carvifolia (subdivision of *Peucedanum* type)
Seseli libanotis type (species in Portugal unknown)
Silaum silaus type (genus in Portugal unknown)
Torilis arvensis type (renamed from *Falcaria vulgaris* type; the latter unknown in Portugal): includes also *Anethum graveolens*, *Ptychotis*
Trinia glauca type: (genus in Portugal unknown)
Umbelliferae indet.

(Urticaceae:)
Urtica.

(Violaceae:)
Viola.

(Valerianaceae:)
Valeriana officinalis
Valerianella.

(Vitaceae:)
Vitis (shrub).

HANDBOOK FOR TRAVELLERS

BY

What has good old **KARL BAEDEKER** to say? Listen .....

1913

The granitic Serra da Estrella, which culminates in the *Malhão* (6530 ft.), sends all its waters to the Mondego, with the exception of the Zézere, which flows S. to the Tagus. It is grazed by numerous flocks of sheep and goats, which produce the raw material for the cloth-factories of Covilhã. !! → Excursions in this region are not advisable except between July 1st and the middle of Sept., and even then the nights are cold. Accommodation and provisions are hardly to be obtained, so that measures must be taken accordingly. The easiest ascent is by the N.W. slope, from the railway stations of *Nellas* and *Gouveia* (p. 547). From Nellas (carriage-hirer, Augusto Rodrigues) a diligence plies to (14 M.) *Ceia* (Hosp. Riffa); fare 510 rs. Gouveia (carr. from Monteiro Canellas) is about 12½ M. from Ceia. Ceia (or *San Romão*, 1½ M. to the S.) is the starting-point for a three-day expedition crossing the Estrella from E. to W. (guide ca. 800, horse or mule ca. 500 rs. per day): on the first day we proceed to the former meteorological observatory of Manteigas (*Poio Negro*, 4905 ft.), about 5 M. to the W. of the village, and thence to the *Lapão do Ronca* (5440 ft.), where we bivouac beneath an overhanging rock; the second day is devoted to several picturesque lakes and to the romantic rugged rocks of the *Cantaros*, the chief lion of the trip; on the third day we ascend the *Malhão* (see above) and begin the return-march. — Less energetic travellers will enjoy a drive to *Manteigas* (2360 ft.; poor night-quarters; see p. 547), whence roads lead to (12½ M.) Gouveia (p. 547), to (24 M.) Guarda (p. 547), and to Belmonte (p. 547).

FLORA AND VEGETATION IN THE SERRA DA ESTRELA, PORTUGAL

A.R. **Pinto da Silva** & A.N. **Teles** (1980/1986), A flora e a vegetação da Serra da Estrela. *Colecção «Parques Naturais»* 7, Serviço Nacional de Parques, Reservas e Património Paisagístico, Lisboa. 52 pp.

Translation by W.O. van der Knaap, 1990.

The large scientific expedition to the Serra da Estrela undertaken in 1881 under the auspices of the Geographical Society of Lisbon included various disciplines, among which was the study of the flora (Henriques 1883). In addition, there has been general botanical interest among those who have studied these mountains, which are the highest mountains in continental Portugal, and which are those most closely associated with Portugal's historical origins. Yet, a floristic and phytosociological monograph with complete and up-to-date information on the vegetation of the Serra da Estrela still has to be produced.

After the early visit of Júlio Henriques, Daveau and Ricardo da Cunha in 1881, many Portuguese and foreign botanists have visited the area. Most of them however merely passed through or stayed only a very short time, as access to the area and staying there was difficult until a few years ago. Nevertheless, the botanical activities of these people have resulted in valuable new additions to the known flora. Also, revisions of herbarium materials by specialists and taxonomists engaged in the production of monographs often resulted in the discovery of new species.

The list of known plant communities composing the vegetation pattern in the Serra da Estrela is still that established by Braun-Blanquet, Pinto da Silva, Rozeira & Fontes (1952). Already in 1945, F.C. Fontes, M. Myre and B.V. Rainha made a thorough floristic and phytogeographic study in the upper parts of the mountains, which was a valuable background for the present study.

The excursion 7-10 August 1973 carried out at the request of the Department of Nature Conservancy (D.-G.S.F.A.) was principally designed to obtain a general impression of not only the ecological conditions and the altitudinal distribution of the plant species which are scientifically and aesthetically most interesting, but also of the zonation and the relative importance of the various plant communities in the Serra da Estrela. The data collected, combined with those from literature, enabled us both to define conservation areas and to establish a preliminary list of plant species and plant communities to be protected by law. These activities should prevent extinction of plant species, some of which are evidently scarce, due to their small distribution area, their being strictly endemic to the Serra da Estrela and present only in small numbers, or to their occurrence as relicts in this part of Portugal, thus being of particular scientific interest.

During the above-mentioned excursion we were accompanied by I.F. Ministro and by J.B.A. Farraia and M.J. Boieiro, experts in the Serra da Estrela and its problems. We are grateful for their valuable collaboration. We also thank J. Inácio for whom the Serra da Estrela and its flora is increasingly opening its secrets, and the warden Mr. J.A. Lopes who was also our useful guide on the arduous mountain tracks.

In April 1977 we made another excursion, this time for the study of the vegetation at the base of the Zêzere valley and at Mestra Brava on the southern slopes of the Serra da Estrela.

The work was part of the regular activities of the Department of Plant Taxonomy and Geobotany (National Agronomic Station) and was submitted for publication free of charge to the National Service of Parks, Reserves and Landscape Patrimony.

FLORA

Within the Portuguese flora, the Herminian vascular-plant flora reflects glacial influences most clearly. The Herminian flora can be considered to be relatively rich and is of great plant-geographic interest, in spite of the predominance of monotonous granitic bedrock which, as is generally known, does not usually favour floristic diversity.

ENDEMIC TAXA

The number of taxa strictly endemic to the Serra da Estrela is very small. It comprises just seven species and subspecies and the same number of varieties and forms. The most interesting are *Festuca henriquesii*, *Silene elegans*, *Angelica angelicastrum*, *Scrophularia herminii* ssp. *herminii*, *Senecio caespitosus*, *Centaurea rothmaleriana* and *Centaurea micrantha* ssp. *herminii*, which are all restricted to the summit region. Only *Rubus genevieri* ssp. *herminicus* occurs at lower altitudes. Only two endemic taxa have been discovered in the last 40 years. In spite of difficult access to these mountains, some endemic taxa were described by Brotero and by Hoffmansegg & Link at the beginning of the nineteenth century.

Among the endemic taxa below the level of species, *Rubus genevieri* ssp. *herminicus*, *Centaurea micrantha* var. *herminii* and *Centaurea rothmaleriana* can probably be considered as neo-endemic taxa. This is also the case with *Epilobium obscurum* var. *herminicum*, *Veronica officinalis* var. *carqueijiana* and *Leucanthemopsis flaveola* var. *flava*. The following taxa might possibly also be considered as neo-endemic: *Potentilla erecta* var. *herminii*, *Galium saxatile* ssp. *vivianum* and *Hieracium schmidtii* var. *herminii*; the original descriptions of these taxa are all based on material from the Serra da Estrela.

Apart from this small group of endemic taxa, eleven taxa (seven species and subspecies and four varieties and forms) should be specially mentioned which were first described based on material from the Serra da Estrela but were later also found in other areas. Taxonomically the most important, having their *locus classicus* in the Serra da Estrela, are *Antinoria agrostidea* ssp. *natans*, *Saxifraga spathularis* (also rather frequent in north-west Portugal, but confined to the Mediterranean region), *Genista florida* ssp. *polygaliphylla* (also frequent in the mountains of north-west Portugal), *Teucrium salviastrum* (a mountain plant in the Serra da Estrela (Rivas-Martinez, 1973) but recently discovered in the Serra do Marão by Pinto da Silva *et al.*, 1976), *Galium saxatile* ssp. *vivianum* (discovered a few years ago by Kliphuis), *Campanula herminii* (perhaps the species to be chosen as a symbol for the Herminian flora) and *Phalacrocarpum oppositifolium* (a beautiful daisy flowering profusely on the ascent to Penhas Douradas in the spring of 1977).

Fifty-seven taxa are endemic and possibly palaeo-endemic for a larger area and have generally a discontinuous distribution. The majority are mountain plants which outside the Serra da Estrela are generally only found in other Portuguese and Spanish mountains, mainly within the 'Carpetano-Ibérico-Leonesa' Province (Rivas-Martinez 1973). Nearly all these taxa are part of the plant-geographic Mediterranean-Iberian sub-element, which is in agreement with the physiographic and climatic (and therefore economic) Mediterranean-Iberian-Atlantic character of the Serra da Estrela – to use again the terminology of Rivas-Martinez. In our opinion, the following taxa belong to this group: *Trisetaria hispida*, *Holcus durieui*, *Festuca elegans*, *Luzula sylvatica* ssp. *henriquesii*, *Luzula caespitosa*, *Allium scorzonerifolium* var. *xericiense*, *Hyacinthoides non-scripta* var. *cernua*, *Narcissus asturiensis*, *Narcissus rupicola*, *Crocus serotinus* ssp. *clusii*, *Rumex suffruticosus*, *Arenaria queriodes* ssp. *querioides*, *Silene herminii* ssp. *herminii*, *Ranunculus abnormis*, *Erysimum merxmuelleri*, *Teesdaliopsis conferta*, *Murbeckiella boryi*, *Reseda gredensis*, *Sedum willkommianum*, *Mucizonia sedoides* (from the Pyrenees and the high mountains of the Iberian Peninsula), *Saxifraga clusii* ssp. *lepismigea*, *Prunus lusitanica* ssp. *lusitanica*, *Echinospartum lusitanicum* ssp. *lusitanicum*, *Genista anglica* ssp. *ancistrocarpa* (also in Marocco), *Genista micrantha*, *Genista cinerea* ssp. *cinerascens*, *Cytisus purgans* (south-west Europe), *Adenocarpus hispanicus* ssp. *argyrophyllus*, *Lotus glareosus* (a mountain plant endemic to southern Spain and central Portugal), *Viola langeana*, *Eryngium duriaei* (ssp. *duriaei* and ssp. *juresianum*), *Angelica laevis* (a Galician-Asturian endemic species), *Ajuga pyramidalis* ssp. *meonantha*, *Antirrhinum ambiguum*, *Scrophularia schousboei*, *Scrophularia herminii* ssp. *bourgaeiana*, *Plantago radicata* ssp. *monticola*, *Jasione crispa* ssp. *sessiliflora* and ssp. *centralis*, *Anthemis canescens*, *Doronicum carpetanum*, *Carduus carpetanus*, *Leontodon pyrenaicus* ssp. *cantabricus*, *Taraxacum algarbiense*, *Hieracium castellanum*, *Hieracium onosmoides* ssp. *cadyense* and *Hieracium peleterianum* ssp. *vansoestii*.

NON-ENDEMIC TAXA

The interest in the Herminian flora is not restricted to the endemic plants. The Serra da Estrela is the only region in Portugal which has so many taxa (21, mainly species and subspecies) with a large distribution in Europe. *Lycopodium clavatum* and *Cryptogramma crispa*, having a mainly central and southern European distribution, are so rare in the Serra da Estrela that only few botanists have been lucky enough to see them; these species should be strictly protected. The holarctic species *Sparganium angustifolium* and *Carex nigra* and the central European *Allium senescens* (which seems to have been collected only once in the Serra da Estrela, but we looked for it in vain) have up to now only been cited as occurring in Portugal in the Serra da Estrela. *Paronychia polygonifolia* ssp. *velucensis* is a remarkable calcifugeous Mediterranean mountain plant which clearly illustrates the special phyto-geographical character of the Serra da Estrela, as does the western Mediterranean *Jurinea humilis*.

The same can be said of *Saxifraga stellaris* ssp. *alpigena*, *Alchemilla transiens*, *Gentiana lutea* and *Plantago serpentina* from central and southern European mountains. Also the north European *Epilobium anagallidifolium*, which is distributed as far southwards as the mountains of Corsica and Yougoslavia, is only known in Portugal in the upper parts of the Serra da Estrela, as is *Veronica serpyllifolia* ssp. *humifusa*, a mountain plant with a wide distribution in Europe. The genus *Hieracium* subgenus *Hieracium* (with its innumerable and usually agamospermous 'micro-species') is represented in Portugal by a considerable number of species only found in the Serra da Estrela, e.g. the central and northern European *H. divisum*, *H. lasiophyllum*, *H. onosmoides* and *H. subcomatulum* and the eastern Mediterranean *H. pallidum* ssp. *comosulum*.

Most of this group of 21 taxa are mountain plants with a wide distribution in Europe, some being restricted to the northern and central part, others to the central and southern part of the continent, and some to the Mediterranean. Each case deserves a thorough analysis, for which there is, however, no place in this study.

There are more than thirty additional taxa (mostly species) occurring in the Serra da Estrela and in other mountains in the north of Portugal which must be mentioned because of their floristic or plant-geographic interest. Eight have a European distribution but are mountain plants only in the south of the continent: *Taxus baccata*, *Juniperus communis* ssp. *alpina*, *Betula alba*, *Malus sylvestris*, *Sorbus aucuparia* ssp. *aucuparia*, *Vaccinium myrtillus* and *Menyanthes trifoliata*. All these plants have a relict character in Portugal and are probably old elements taking refuge in the mountains after the Late-Glacial period. *Pinus sylvestris*, which according to Romariz (1950) has grown in the Serra da Estrela but is today restricted to the Serra do Gerês in Portugal, possibly also belongs to this group.

Among the central, southern and western European mountain plants worth mentioning are *Dryopteris abbreviata*, *Poa supina* (which escaped the eyes of our botanists but not those of the master of phytosociology Braun-Blanquet ...), the beautiful *Allium victorialis* (which we were so lucky to find in Trás-os-Montes on the outskirts of the Serra do Gerês), the tiny *Cerastium gracile*, *Minuartia recurva* ssp. *recurva*, *Sorbus torminalis*, *Acinos alpinus* ssp. *meridionalis* and *Galium saxatile* ssp. *saxatile*.

Taxa to be mentioned which are mountain plants in Portugal but not elsewhere, are the very rare *Veratrum album* (observed by only few investigators of the Herminian flora), *Sorbus latifolia* and *Prunus padus* ssp. *padus* (very rare in the Serra da Estrela).

It is very improbable that the plundering to which bulb-hunters are dedicated with such egoistic tenacity will allow us to encounter today *Narcissus pseudonarcissus*, so infrequent in Portugal ... *Taraxacum* in this group is represented by *T. nordstedtii* and *T. sundbergii* from northern and central Europe and by *T. panalpinum* from southern Europe, which are, at least in the southern part of their distribution, probably all mountain plants. If the evidence by the late *Hieracium* specialist Van Soest is accepted, seven more central and southern European *Hieracium* species, in addition to those already mentioned occur in the Serra da Estrela.

VEGETATION

The high altitude of the Serra da Estrela gives rise to a well-defined and very interesting vegetation zonation. Three vegetation zones can easily be observed, with height limit inevitably varying with the side of the Serra da Estrela under consideration. The zones are:

1. **Basal zone**, with a marked Mediterranean influence, from the foot of the mountains up to 800-900 m.
2. **Middle zone**, corresponding with the zone of *Quercus pyrenaica* dominated climax vegetation, between (600-)800 and 1600 m.
3. **Upper zone**, dominated by *Juniperus communis* ssp. *alpina*, above 1600 m.

BASAL ZONE

The basal zone (Figs. 1 and 2) includes the settlements scattered along the foot of the Serra da Estrela. Agricultural activities are relatively strong here. In this zone particularly olive trees (up to 800 m in São Romão and up to nearly 900 m in Seia and Manteigas), vineyards, maize fields, Italian Rye-grass fields (*Lolium multiflorum*), and stands of *Pinus pinaster* (growing up to ca. 1300 m) are found.

Natural vegetation in this zone is virtually absent due to agricultural activity. The notable occurrences of Evergreen Oak (*Quercus rotundifolia*) in the valley of Rio Zêzere and at Mestra Brava near Loriga are therefore more striking. In this interesting and rather inaccessible locality there are remarkable galleries of Portuguese Laurel Cherry (*Prunus lusitanica*) in two or three ravines incised into the mountain slope.

1. EVERGREEN-OAK GROVES (*Quercus rotundifolia*)

The relics of Evergreen Oak (*Quercus rotundifolia*) groves are found in the Rio Zêzere valley between Valhelhas and Vale de Amoreira growing on the base of steep schistose slopes below the road at ca. 550 m (Fig. 1). The groves include *Quercus rotundifolia*, *Phillyrea angustifolia*, *Daphne gnidium*, *Arbutus unedo*, *Rubia peregrina*, *Olea europaea* var. *sylvestris*, *Tamus communis*, *Crataegus monogyna* ssp. *brevispina*, *Cistus ladanifer*, *Erica arborea*, *E. australis*, *E. umbellata*, *Calluna vulgaris*, *Urginea maritima*, *Astragalus lusitanicus*, with *Thapsia villosa*, *Pimpinella villosa*, *Helichrysum stoechas*, *Carlina corymbosa* and *Epipactis helleborine*. The presence of *Pinus pinaster* represents an alarming invasion from the surrounding pine woods.

Note: It is presumed that in earlier times Evergreen-Oak forests and accompanying vegetation had a wider distribution at higher altitudes. This is confirmed by the toponyms 'Azinha' (a summit at 1272 m) and 'Azinheira' (a summit at 1035 m) near Vale de Amoreira. The bedrock formed by the Schist-Greywacke Complex in this part of the Serra da Estrela known as the 'Serra Mansa', contrasting with the higher and more cultivated south-western 'Serra Brava' (see Link, *Voyage en Portugal* 2: 82), could also be favourable for this vegetation.

The remnants of Evergreen-Oak groves at Mestra Brava (Fig. 2) are also endangered by invasion of *Pinus pinaster*. They grow on the steep slope above the Loriga rivulet, where many small schistose outcrops are present. The grove seems to have its optimum development at the base of the slope. The species composition is similar to that of the grove in the valley of Rio Zêzere. The growing conditions must therefore be similar, although at Mestra Brava they are less dry due to a north exposition. The additional presence of *Viburnum tinus* and *Quercus suber* should be noted.

2. STANDS OF PORTUGUESE LAUREL CHERRY (*Prunus lusitanica*)

The galleries of Portuguese Laurel Cherry (*Prunus lusitanica* ssp. *lusitanica*) at Mestra Brava near Loriga (Fig. 2) grow in ravines or 'barrocas' incised into the steep north-exposed slope between 900 and 500 m. The occurrence of these mesophytic communities within the Evergreen-Oak groves is possible due to relatively humid soil conditions. Apart from *Prunus lusitanica* (up to 8 m high and up to 15 cm in diameter), the following taxa are present: *Crataegus monogyna* ssp. *brevispina*, *Viburnum tinus*, *Erica arborea*, *Lonicera periclymenum*, *Frangula alnus*, *Hedera helix* ssp. *canariensis*, *Arbutus unedo*, *Castanea sativa*, *Ruscus aculeatus*, *Quercus pyrenaica*, with *Blechnum spicant*, *Athyrium filix-femina*, *Pteridium aquilinum*, *Genista falcata*, *Erica scoparia*, *Primula vulgaris*, *Asplenium onopteris* and *Sedum forsteranum*.

The stand of *Prunus lusitanica* at Mestra Brava (see Pinto da Silva *in* Braun-Blanquet *et al.*, 1956) resembles that which occurs in the forest of (Mata de) Álvaro (in the middle of the Rio Zêzere valley near Oleiros, between 625 and 850 m). It also resembles, but less closely, that which occurs in the forest of Margaraça (near Relva Velha, Arganil, altitude 600 m, north-north-west exposure). For reasons given in Braun-Blanquet (1956), the stand at Mestra Brava could be a *Prunus lusitanica* variant of the thermophytic subassociation viburnetosum of the Rusco-Quercetum roboris, at the southern limit of this association. The laurel-leaved taxa finding favourable conditions in this variant are *Prunus lusitanica*, *Laurus nobilis*, *Ilex aquifolium*, *Arbutus unedo*, *Viburnum tinus* and *Hedera helix* ssp. *canariensis*.

This community also appears to be related to the Viburno-Prunetum lusitanicae, which was recently described by Ladero (1976) as found in the eastern part of the (Spanish) Luso-Estremaduran province. However, *Quercus faginea* occurs in the latter association and several Atlantic species recorded in the Portuguese stands are absent. The weak characterization of the Spanish association by the single taxon *Prunus lusitanica* makes its syntaxonomic position questionable. In view of the importance of taxa of the regional climax associations in the Spanish and Portuguese *Prunus lusitanica* stands, it is preferred to consider such stands as a mere variants determined by special humid soil conditions.

MIDDLE ZONE

The predominant natural and semi-natural vegetation types in the middle zone (Figs. 3 and 4) are Deciduous-Oak forest and a number of shrubland types. Although not naturally occurring, the chestnut groves named 'Souto do Concelho' near Manteigas and rye-fields will also be discussed.

1. DECIDUOUS-OAK FOREST

Cutting, burning and grazing are the causes of the marked decline of the Deciduous-Oak forests. Today, these forests are only found as impoverished and small relics. Also, the introduction of exotic trees by the Forestry Department has contributed to the scarcity of Deciduous-Oak forests today. Deciduous-Oak groves belonging to the association of Holco-Quercetum pyrenaicae are found at Carvalheira between Penhas Douradas and Manteigas at 1240 m, near Poço do Inferno at 1000 m and at Moita do Conqueiro between Covão do Urso and Lagoa Redonda at 1500 m. The first two sites are coppiced and rather open, and have been disturbed by man. At these sites Deciduous Oak (*Quercus pyrenaica*) reaches a height of up to 15 m, is up to 40-50 cm thick and has a remarkably vigorous growth.

The presence of a few *Pinus pinaster* trees in the Deciduous-Oak grove at Carvalheira and the adjacent plantation of *Pseudotsuga* (where the trees reach remarkable heights) are factors requiring special attention with regard to the conservation of this grove, apart from the fact that the City Corporation of Manteigas seems to be planning to sell its wood.

Note: This 'large forest of oaks' has already been referred to by Link (*Voyage en Portugal* 3: 142-143, 1805) in the description of his fourth journey to the Serra da Estrela. He passed by it on 13th August 1800.

These Deciduous-Oak groves include Deciduous Oak (*Quercus pyrenaica*), *Q. robur*, *Sorbus aucuparia*, *Castanea sativa*, *Lonicera periclymenum*, *Erica arborea*, *Sarothamnus grandiflorus*, *Cytisus multiflorus*, *Genista falcata*, *Pteridium aquilinum*, *Arenaria montana*, *Silene nutans*, *Viola riviniana*, *Clinopodium vulgare*, *Prunella hastifolia*, *Crepis lampsanoides*, *Linaria triornithophora*, *Physospermum cornubiense*, *Cruciata glabra*, *Galium rotundifolium*, *Festuca elegans*, *Holcus mollis*, *Geranium lucidum*, *Teucrium scorodonia*, *Digitalis purpurea*, *Sedum forsteranum*, *Melandrium album* (= *Silene alba*), *Hyacinthoides hispanica*, *Hieracium sabaudum* and *Erysimum merxmuelleri*. *Juniperus communis* ssp. *alpina* occurs at a relatively low altitude in these groves.

According to observations made during a recent excursion, the upper limit of *Quercus pyrenaica* is at ca. 1700 m and is formed by the occurrence of shoots between the rocks of the Cântaro Raso along the road from Nave de Santo António to Covão do Boi. Barros (1934) mentions the occurrence of this species between 1200 and 1700 m and Rivoli (1881) reports the occurrence of groves including *Quercus* spp., *Taxus baccata*, *Betula alba*, *Castanea sativa*, *Ilex aquifolium* and *Arbutus unedo* at various localities up to 1750 m in the Serra da Estrela.

Taxus baccata, a species clearly reduced in number, was observed in an incision in the slope with the road from Manteigas to Covão da Metade, near to the latter, at ca. 1350 m. Some trees, accompanied by *Erica arborea*, occur on the sands of the rivulet 'Ribeira do Teixo' at 1560 m, and at a few other places.

2. CHESTNUT GROVES (*Castanea sativa*)

Chestnut groves grow on rather steep, north-exposed slopes with schistose, or more rarely, granitic bedrock. The chestnut groves of the so-called 'Souto do Concelho' extend over a large area between 600 and 1100 m on the shaded slopes east of Manteigas; they contrast significantly with the decimated Evergreen-Oak groves discussed above on the opposing sunlit slopes. The chestnut groves of Valhelhas also extend over a large area.

Significant taxa in these chestnut groves, relicts from the *Quercus pyrenaica* climax forests, are *Castanea sativa* itself, occasional shoots of *Quercus pyrenaica*, *Melittis melissophyllum*, *Viola riviniana*, *Arenaria montana*, *Genista falcata*, *Pteridium aquilinum*, *Lonicera periclymenum*, *Clinopodium vulgare*, *Ilex aquifolium*, *Silene nutans*, *Teucrium scorodonia*, *Holcus mollis*, *Galium rotundifolium*, *Brachypodium sylvaticum*, *Hieracium sabaudum*, *Lathyrus montanus*, *Festuca elegans*, *Digitalis purpurea*, *Luzula forsteri*, *Primula vulgaris*, *Asplenium adiantum-nigrum*, *Prunus avium*, *Sedum forsteranum*, *Dactylis glomerata*, *Crataegus monogyna* ssp. *brevispina* and *Hedera helix* ssp. *canariensis*. Species indicating somewhat warmer conditions are present in chestnut groves in comparable conditions near Fundão in the Serra de Gardunha: *Daphne gnidium*, *Paeonia broteroi*, *Origanum virens*, *Geranium robertianum* ssp. *purpureum* and also *Allium massaessylum*.

Within the chestnut groves, schistose debris slopes are sometimes present with an interesting vegetation including *Umbilicus rupestris*, *Saxifraga continentalis*, *Rumex scutatus* ssp. *induratus*, *Pisum sativum* (ssp. ?), *Aristolochia longa*, *Geranium purpureum*, *Geranium lucidum*, *Tamus communis*, *Cardamine hirsuta*, *Arabis* spec. and *Rubia peregrina*.

3. SHRUBLANDS

Degradation of the forests has led to the formation of extensive shrublands. The White-broom scrub of *Cytisus multiflorus*, the heathlands of *Erica australis* ssp. *aragonensis* and the riverine-broom scrub of *Genista florida* ssp. *polygaliphylla* will be discussed here.

a. White-broom scrub of *Cytisus multiflorus*

The White-broom scrub of *Cytisus multiflorus* is widespread below 1500 m. It has been described as Lavandulo-Cytisetum multiflori. It is extremely poor in species, which is possibly due to periodical ploughing for the establishment of rye fields (*Secale cereale*). It includes *Cytisus multiflorus*, *Lavandula stoechas* ssp. *sampaiana*, *Pteridium aquilinum*, *Cytisus striatus*, *Erica arborea* and *Halimium alyssoides*.

Of uncertain syntaxonomic position are the rock-rose fields of *Halimium alyssoides*, which locally occupy extensive areas on much degraded soils, e.g. near Penhas Douradas at ca. 1400 m.

b. Heathlands of *Erica australis* ssp. *aragonensis*

The heathlands of *Erica australis* ssp. *aragonensis* are rarely ploughed and therefore less influenced by man than the White-broom scrub, and are only subject to grazing and burning This explains why species richness is greater here than in the white-broom scrub. The heathlands have been described as Junipero-Ericetum aragonensis and include *Erica australis*, *Juniperus communis* ssp. *alpina* (which transgresses from the upper zone above

1600 m where it reaches its optimum), *Erica arborea*, *Halimium alyssoides*, *Calluna vulgaris*, *Luzula lactea*, *Pteridium aquilinum* and in places also shoots of *Quercus pyrenaica*.

Adenocarpus hispanicus ssp. *argyrophyllus*, a fine taxon endemic to the western Iberian peninsula, occurs also in the Serra da Estrela (Covão da Metade, Candeeira). It grows on stony soils, as it does in other areas, for example in the area between Monfortinho and Penha Garcia (Teles, 1980).

c. Riverine-broom scrub of *Genista florida* ssp. *polygaliphylla*

The Riverine-broom scrub of *Genista florida* ssp. *polygaliphylla* is frequent at the base of slopes. Somewhat cool conditions at these sites are reflected in the occurrence of *Genista florida* ssp. *polygaliphylla*, associated with *Cytisus striatus* and *Pteridium aquilinum*. This riverine-broom scrub, or fragments of it, belong possibly to the Genisto-Cytisetum striati Rivas-Martinez (ined.).

4. RYE FIELDS (*Secale cereale*)

Today rye fields (*Secale cereale*) are scattered and rather few. They have been made on very poor soils and are found locally up to 1600 m. The vegetation in these fields is described as Catapodietum patentis and is characterized by *Micropyrum patens*, *Avena strigosa*, *Anthoxanthum aristatum*, *Spergula arvensis*, *Vicia angustifolia*, *Anthemis arvensis*, *Rumex angiocarpus* and *Chrysanthemum segetum*.

UPPER ZONE

On the basis of pollen analysis carried out by Romariz (1950) on peaty deposits from two former glacial lakes (Lagoa Comprida and Lagoa dos Covões) it must be concluded that *Pinus sylvestris*, *Betula* and *Taxus* occupied the upper part of the Serra da Estrela after the retreat of the Würmian glaciers. The highest areas of the Serra da Estrela are today, however, totally devoid of trees due to intense deforestation and probably a xerothermic period.

According to Romariz (1950), *Juniperus* was present in the Serra da Estrela after *Pinus sylvestris*, and expanded considerably replacing the original forest vegetation. This must be due to the easy dispersal of juniper berries by birds and the preservation of junipers by the shepherds. They are preserved not only because of the value of the berries, which are collected at the end of the summer, but also because juniper wood is preferred to heather or *Quercus pyrenaica* shoots for charcoal burning.

The heathlands on the summits of the Serra da Estrela seem to be syntaxonomically unrelated to those in the subalpine region of the Alps and Pyrenees (Duvigneaud, 1962). The upper zone is therefore rather a pseudo-alpine zone, which is also shown by the abundance of *Erica arborea* and by the modest importance of subalpine species.

The vegetation of the upper zone of the Serra da Estrela includes juniper scrub, mat-grass lawns, open grass fields and saxicolous and lake communities. The predominant pattern of vegetation types is a mosaic of juniper scrub and mat-grass lawns, with peculiar open grass fields formed by granitic 'carapaces', frequently interrupted by rocky outcrops and by the unexpected appearance of a peaceful lake.

1. JUNIPER SCRUB

The Junipero-Ericetum aragonensis of the middle zone is replaced above 1600 m by the Lycopodio-Juniperetum nanae, which includes *Juniperus communis* ssp. *alpina*, *Cytisus purgans*, *Erica arborea*, *Calluna vulgaris*, *Narcissus bulbocodium* var. *nivalis*, *Festuca indigesta* and *Deschampsia flexuosa*. This community is very poor in species. The proportion of Ericaceae decreases with increasing altitude, as can be observed during the ascent of the Cântaros from Nave de Santo António. The juniper scrub reaches its optimum in the summit region, where extensive areas of non-overlapping pure juniper occur, rounded by the wind, occasionally accompanied by *Erica arborea*.

We only saw *Cytisus purgans* on the north-eastern side of the Serra da Estrela, which suggests that this broom species is associated with continental conditions. The 'finicolous' species *Lycopodium clavatum*, which could be becoming extinct in the Serra da Estrela, might also be found in this community. *Vaccinium myrtillus* also possibly belongs to this community, and was by chance only observed associated with *Erica arborea*, *Juniperus communis* ssp. *alpina* and *Luzula caespitosa*.

Echinospartum lusitanicum, *Genista cinerea* ssp. *cinerascens*, *Teucrium salviastrum* and also *Phalacrocarpum oppositifolium* are associated too with creeping junipers, They were observed at the base, and in fissures, of rock formations or 'Tors'. Rivas-Martinez (1974) suggests a new association for this community, the Teucrio salviastri-Echinospartetum pulviniformis.

At various places within the district of Guarda we observed that at lower altitudes *Echinospartum lusitanicum* grows in a different vegetation type, although still in rocky granitic areas, together with *Genista cinerea* ssp. *cinerascens*, *Cytisus multiflorus*, *Stipa gigantea*, *Trisetaria hispida* and *Digitalis thapsi*.

2. MAT-GRASS LAWNS (*Nardus stricta*)

Mat-grass lawns are important for sheep and goat pasture during transhumance. They are mainly found on colluvial soils in valleys high in the Serra da Estrela. In these valleys, the availability and the retention capacity of water from rains and snow-melt are highest. Two vegetation types can be distinguished: dry Mat-grass lawns described as Galio-Nardetum, and moist Mat-grass lawns described as Junco-Sphagnetum compacti.

a. Dry Mat-grass lawns (Galio-Nardetum)

Typical Mat-grass lawns (Galio-Nardetum) are found in e.g. Nave de Santo António, Covão do Boi, Vale das Éguas, Vale do Conde and Vale de Loriga. Their fresh green aspect even in high summer lends an impressive beauty to the summits of the Serra da Estrela, which otherwise have a certain austerity.

Plants known to occur in the Galio-Nardetum are *Nardus stricta* as a dominant, *Juncus squarrosus*, *Galium saxatile*, *Potentilla erecta*, *Luzula campestris*, *Festuca rubra*, *Narcissus bulbocodium* var. *nivalis*, *Hieracium pilosella*-group, *Polygala vulgaris*, *Pedicularis sylvatica*, *Rumex angiocarpus*, *Merendera pyrenaica*, *Festuca indigesta*, *Ranunculus nigrescens* and *Lotus corniculatus*. *Campanula herminii* should in our view also be included in this list. This species is also found in rock crevices, but according to our observations it is frequent and has its optimum in Mat-grass lawns. *Juniperus communis* ssp. *alpina* and *Calluna vulgaris* invade occasionally into Mat-grass lawns and replace it.

b. Moist Mat-grass lawns (Junco-Sphagnetum compacti)

The Junco-Sphagnetum compacti growing on peaty soil is differentiated from the Galio-Nardetum by its richness in the mosses *Sphagnum* spp. and *Aulacomnium palustre*. The association includes *Nardus stricta*, *Juncus squarrosus*, *Potentilla erecta*, *Gentiana pneumonanthe*, *Pedicularis sylvatica*, *Carex echinata*, *Viola palustris* ssp. *juressi*, *Narcissus bulbocodium* var. *nivalis*, *Sphagnum compactum*, *Sphagnum molle* and *Aulacomnium palustre*. *Drosera rotundifolia* is occasionally present.

3. OPEN GRASS FIELDS

The degradation of Mat-grass lawns due to overgrazing favours erosion by water during rains and snow-melt. This results in open areas characterized by a superficial layer of fine granitic gravel, consolidated as a shield on a rather deep soil. These open areas are colonized by communities belonging to the Arenario-Cerastietum ramosissimi, which is developed in several variants. The most important taxa in this association are *Arenaria aggregata* ssp. *aggregata*, *Agrostis durieui*, *Cerastium gracile*, *Paronychia polygonifolia* ssp. *velucensis*, *Rumex angiocarpus*, *Sedum anglicum*, *Sedum brevifolium*, *Anthoxanthum aristatum*, *Molineriella laevis*, *Spergularia capillacea*, *Poa bulbosa* and the mosses *Polytrichum juniperinum* and *P. piliferum*.

On the bare and rough soils in the summit region of the Serra da Estrela, e.g. near Fonte dos Perús, the open grass fields of the Arenario-Cerastietum ramosissimi are replaced by related psychro-xerophytic communities. They include mainly the scattered flattened plants of *Plantago radicata* ssp. *monticola* and *Minuartia recurva*. According to Rivas-Martinez (1974), this community is a fragment of the 'Bejarano-Gredense' association of Agrosto-Minuartietum (juressi) recurvae, or, which is more plausible, a distinct vicariant association.

4. SAXICOLOUS COMMUNITIES

As one approaches the summits of the Serra da Estrela, the rock formations become increasingly majestic, culminating in the renowned Cântaros.

The saxicolous vegetation is poorly developed in open and rather dry areas, but it is rich and very interesting on the steep sides of natural mountain gorges which are protected from the sun. The majority of endemic species and of mountain plants noteworthy for the Serra da Estrela are found here. In cool conditions, as in the Rua dos Mercadores and in the gorge going down to Lagoa do Peixão, we saw beautiful carpets dominated by *Saxifraga spathularis* or by *Silene foetida*. *Murbeckiella boryi* usually grows hidden in low horizontal fissures, where the necessary protection and shade are provided.

This vegetation type has been described as Murbeckiello-Saxifragetum. It includes *Saxifraga spathularis*, *Murbeckiella boryi*, *Silene foetida*, *Silene herminii*, *Silene elegans*, *Campanula herminii*, *Festuca henriquesii*, *Narcissus rupicola*, *Leontodon hispidus*, *Leontodon pyrenaicus* ssp. *cantabricus*, *Sedum anglicum*, *Sedum hirsutum*, *Sedum brevifolium*, *Conopodium majus* var. *gracile*, *Alchemilla transiens*, *Rumex suffruticosus*, *Jasione crispa* ssp. *centralis* and ssp. *sessiliflora*.

The floor of some gorges, e.g. that of the Rua dos Mercadores, is covered with stones and levelled by a turf of Mat-grass (*Nardus stricta*), amongst which other species also occur, e.g. *Festuca henriquesii*, *Campanula herminii*, *Angelica angelicastrum*, and *Gentiana lutea*, very rare today. The survival of the latter is endangered also because it is avidly collected, reputedly because of its popular use against Malta fever.

5. LAKE COMMUNITIES

Sampaio (1911) gave a short description of floating vegetation in lake margins and ponds; we observed such vegetation in Lagoa do Peixão and in ponds near Lagoa Comprida and Fonte dos Perús. It usually consists of *Antinoria agrostidea* ssp. *natans*, *Ranunculus lusitanicus*, *Drepanocladus fluitans* and *Fontinalis antipyretica*, forming the Fontinalo-Ranunculetum lusitanici. This inner zone is followed by a marginal zone dominated by *Antinoria agrostidea* ssp. *agrostidea*. The Junco-Sphagnetum compacti follows in the zonation sometimes the aquatic vegetation.

Only in the pond known as Charca das Favas or Lagoacho das Favas ('Lake of the Horse-beans') is *Menyanthes trifoliata*, which is so rare in Portugal, found in the floating vegetation. *Menyanthes* penetrates the central zone of this small lake. The resemblance of its leaves to leaves of the Horse-bean plant ('faveira') is the reason for the name of this small lake.

PROTECTION OF FLORA AND VEGETATION

The best way to protect interesting plants is to protect areas with plant communities including these plants. However, protection of such areas is not always possible or justified and species to be protected sometimes occur outside their proper communities. It can therefore be better to study the flora and regulate its protection.

Species deserving attention and total protection are those restricted to the Serra da Estrela, those which also occur in other Portuguese and Spanish mountains, and those which reach their western or southern limits in the Serra da Estrela.

Certain species are collected on a large scale for various aims, and are endangered as a consequence. *Gentiana lutea* is today endangered because of greedy collection for medical purposes, as mentioned before. Only thanks to the difficult ascent of the majestic Cântaros and to the inaccessibility of some other habitats, such as the Rua dos Mercadores, does this beautiful gentian survive with some few individuals.

The substantial collection of bulbs of *Narcissus* and other Monocotyledons for commercial purposes, which is so destructive to the Herminian flora, should be prevented, but at the same time an alternative should be sought for this modest source of income to the mountain people!

Rye fields should not be permitted, unless there is no risk of soil erosion, which is responsible for the destruction of pastures and even for the impoverishment of the fertile fields of Baixo Mondego.

It is also fundamental to protect the flora of the Serra da Estrela against the introduction of improper taxa (as is, alas, not done in the Serra do Gerês!). Such introductions are not rarely carried out by the Official Services. Taxa introduced are either exotic, mainly conifers (which have an adverse influence on soils), or belonging to the Portuguese flora (e.g. *Pinus sylvestris*) but represented in Portugal probably by different genetic forms. This can lead to irreversible genetic pollution of genetic material of potential economic importance. Indigenous genetic material can even get lost, since most seeds used in forestry are most probably not autochthonous, but derived from other geographical variants or strains.

Note: This was done through the introduction of *Fagus sylvatica* all over the beautiful Serra do Gerês and by the simultaneous destruction of the 'Geira Romana' in order to facilitate the building of a forest road. This is a serious offence against nature and it must be exposed in order to enable restoration - for the good of Science and in the national interest.

The proposed strict botanical reserves have been chosen for the preservation of ecosystems of special scientific value and happen to represent the most beautiful landscapes in the Serra da Estrela.

The areas above 1600 m with juniper climax vegetation are of major interest because of the rare vegetation type; outside the Serra da Estrela this type is only locally present in the Serra do Gerês.

The ecological balance of the creeping juniper scrub can be maintained only when the destructive activities of man are prevented. The mat-grass lawns (Nardetum), however, need more care, lest the balance between soils, plants and animals be disturbed. Regulation of pasture is the basis for conservation of these interesting communities. It is evident that the 'futuristic' huts in the Nave de Santo António should disappear ... and that a new camp site should be created at the same time, in an area without special importance as regards environmental protection, without permanent huts, traders, garages built of brick, pollution of fountains, and litter all over the place. But the necessary infra-structure should also be provided for passing tourists, so that they do not pollute the localities they use for picnicking.

The saxicolous vegetation, which includes many of the most interesting mountain plants, does not seem to need more than the prevention of plant-hunting done by certain botanists and lovers of rarities.

The vegetation of the moist zones in the upper part of the mountain, which is bio-ecologically so important, requires a total protection that safeguards its delicate habitat conditions.

At lower altitudes, the remaining Deciduous-Oak groves, the chestnut groves, the vegetation along streams (alder groves (*Alnus glutinosa*) and willow groves (*Salix* spp.)) and the relics of Evergreen-Oak groves in the valleys of Rio Zêzere and Ribeira da Loriga should be protected.

It is hoped that the persons who will be responsible for the highest mountains in Portugal and the westernmost in Europe (notwithstanding the actual state of affairs in Nature Parks and Reserves) do not forget the scientific, cultural and economic importance of the vegetation cover of the Herminian Mountains, the heart of Lusitania.

General Botanical Reserve

The boundaries of the General Botanical Reserve should coincide as closely as possible with those of the Parque Natural da Serra da Estrela.

Strict Botanical Reserves

1. Lagoa Seca – Candieira – Fonte de Paulo Luís Martins (including the cascade) – Covão da Metade – Poio do Judeu – Espinhaço do Cão – Covão do Boi – Estrela (Torre) – Terroeiro – Malhão Grosso – Penha dos Abutres – Ribeira da Nave – Lagoa da Ribeirinha – Fonte dos Perús – Lagoa Escura – the margin of the east part of Lagoa Comprida – Covão do Vidoal – Lagoa Seca.
   Within this reserve, areas of particular interest are:
   A. Covão do Vidoal – Lagoa Redonda up to Lagoa Comprida – Lagoa Escura – Barros Vermelhos – Covão do Vidoal.
   B. Covão do Ferro – Lagoa do Peixão – Cântaro Gordo – Covão da Metade – Poio do Judeu – Espinhaço do Cão – Covão do Boi – Estrela (Torre) – Fonte dos Perús – Covão do Ferro.
   C. Covão do Boieiro – Lagoa do Covão das Quelhas – Lagoa Serrano – Covão do Meio – Covão do Boieiro.
2. Mestra Brava.
3. Carvalheira.
4. Some remains of Deciduous-Oak groves and Souto do Concelho.
5. Mata do Fragusto and Serra da Cabeça Alta up to the left bank of Rio Zêzere, from Sameiro to Valhelhas.
6. Poço do Inferno.
7. Moita do Conqueiro (between Lagoa Redonda and Covão do Urso).

Flora and vegetation should be protected in areas 1, 6 and 7; only vegetation should be protected in areas 2, 3, 4 and 5.

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Photograph captions

(p. 29) *Sorbus aucuparia* in Vale da Candieira, alt. 1400 m

(p. 31) *Halimium alyssoides* near Vale do Rossim, alt. 1400 m

(p. 32) degraded heathlands in mosaic with open grass fields of *Agrostis durieui* near Fragões das Penhas Douradas, alt. 1550 m

(p. 33) Riverine-broom scrub of *Genista florida* ssp. *polygaliphylla* in the upper Zêzere valley, alt. between 1300m and 1400 m

(p. 34) Mat-grass lawns and Juniper scrub at Charcas, alt. 1800 m

(p. 35) creeping Juniper scrub at Covão das Lapas, alt. 1650 m

(p. 36) hemispheres of *Echinospartum lusitanicum* between the rocks at the mouth of Vale da Candeeira, alt. 1450 m

(p. 37) grazing of the Mat-grass lawns in Vale do Conde, alt. 1600 m

(p. 38) Mat-grass lawn with *Campanula herminii* and *Galium saxatile* near the Cântaros, alt. 1900 m

(p. 39) moist Mat-grass lawn with *Gentiana pneumonanthe* invaded by junipers near Cume, alt. 1800 m

(p. 40) moist Mat-grass lawn with *Drosera rotundifolia* and *Juncus squarrosus* near Cume, alt. 1800 m

(p. 41) open grass fields on fine granitic gravel with *Minuartia recurva* ssp. *recurva* near Cume, alt. 1850 m

(p. 42) vegetation of rock crevices with *Silene elegans*, *Minuartia recurva* and *Campanula herminii*

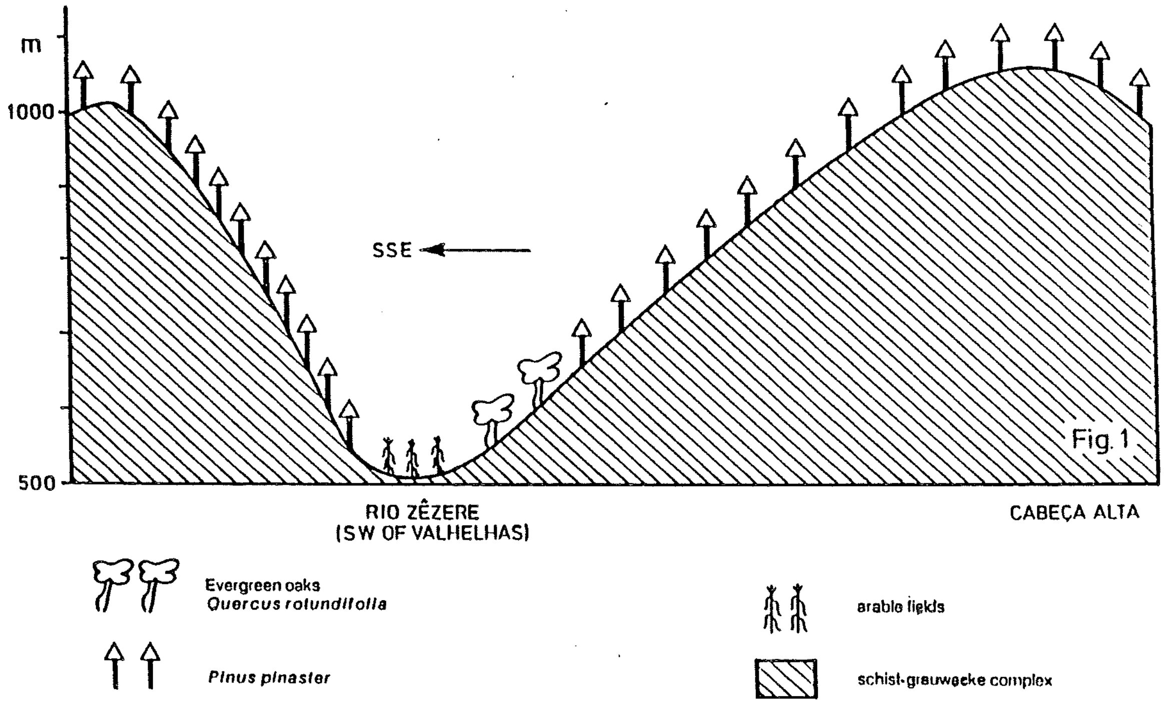
(p. 43) lake vegetation with *Menyanthes trifoliata* and *Antinoria agrostidea* ssp. *natans* in Lagoacho das Favas, alt. 1650 m

(p. 44) *Antinoria agrostidea* ssp. *natans* in Lagoa do Peixão, alt. 1650 m

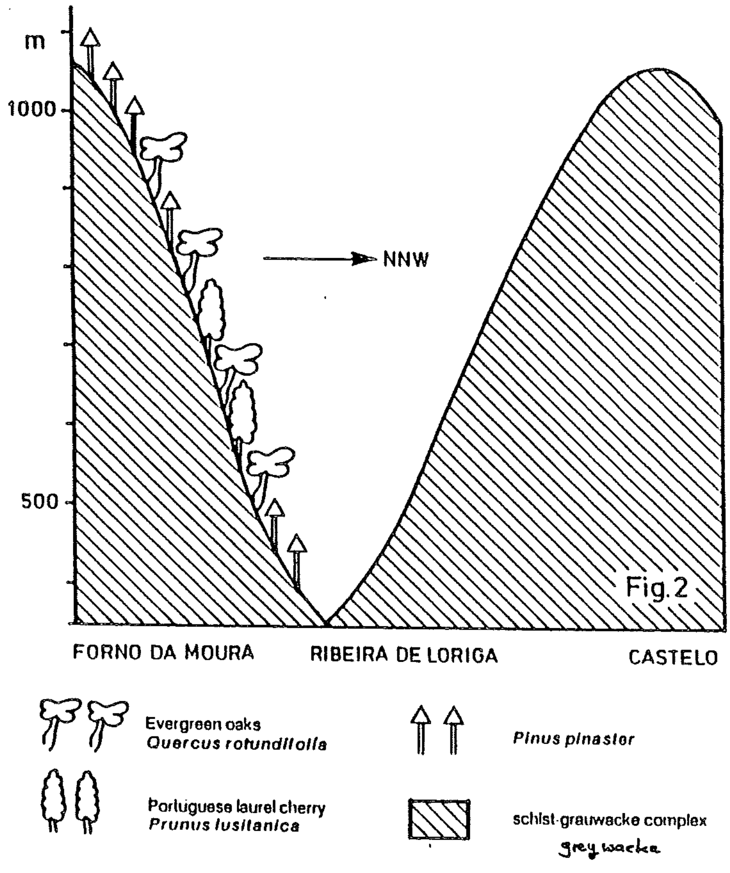
(p. 46) burning of junipers results in the establishment of a mat of *Agrostis durieui* near Charcas, alt. 1800 m

(p. 47) the lack of infra-structure results in lots of rubbish in Covão do Boi ...

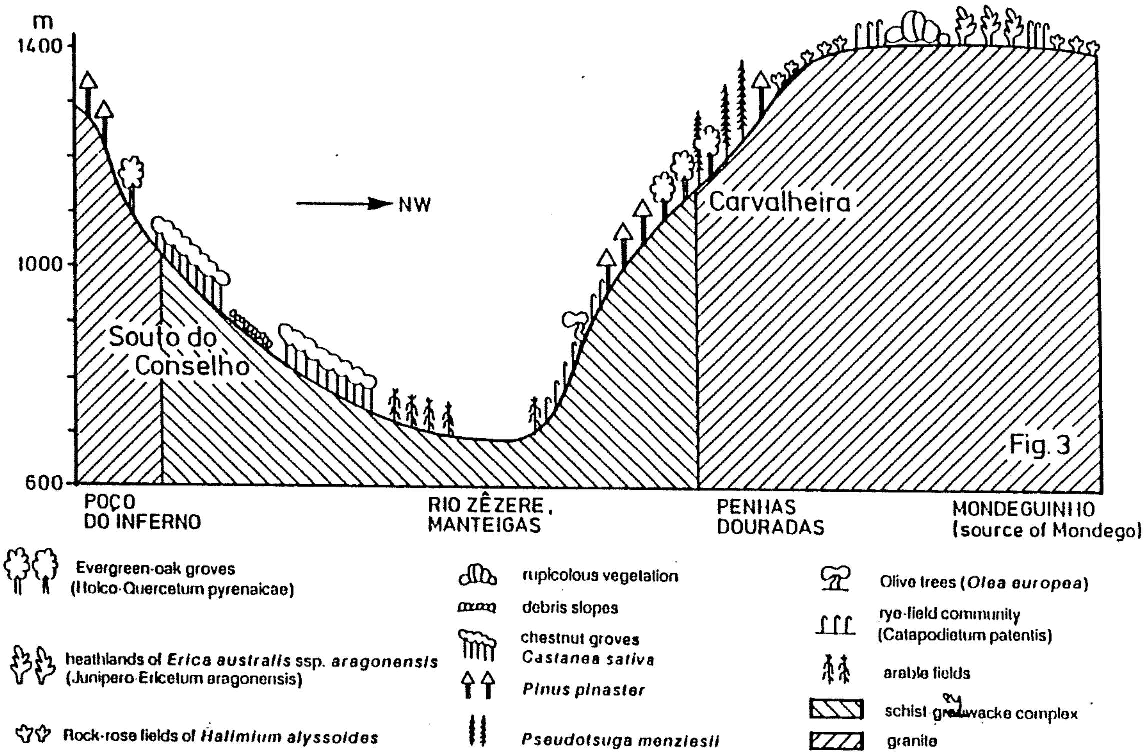
(p. 48) the Mat-grass lawns of Nave de Santo António are invaded by permanent-looking sheds and even garages!

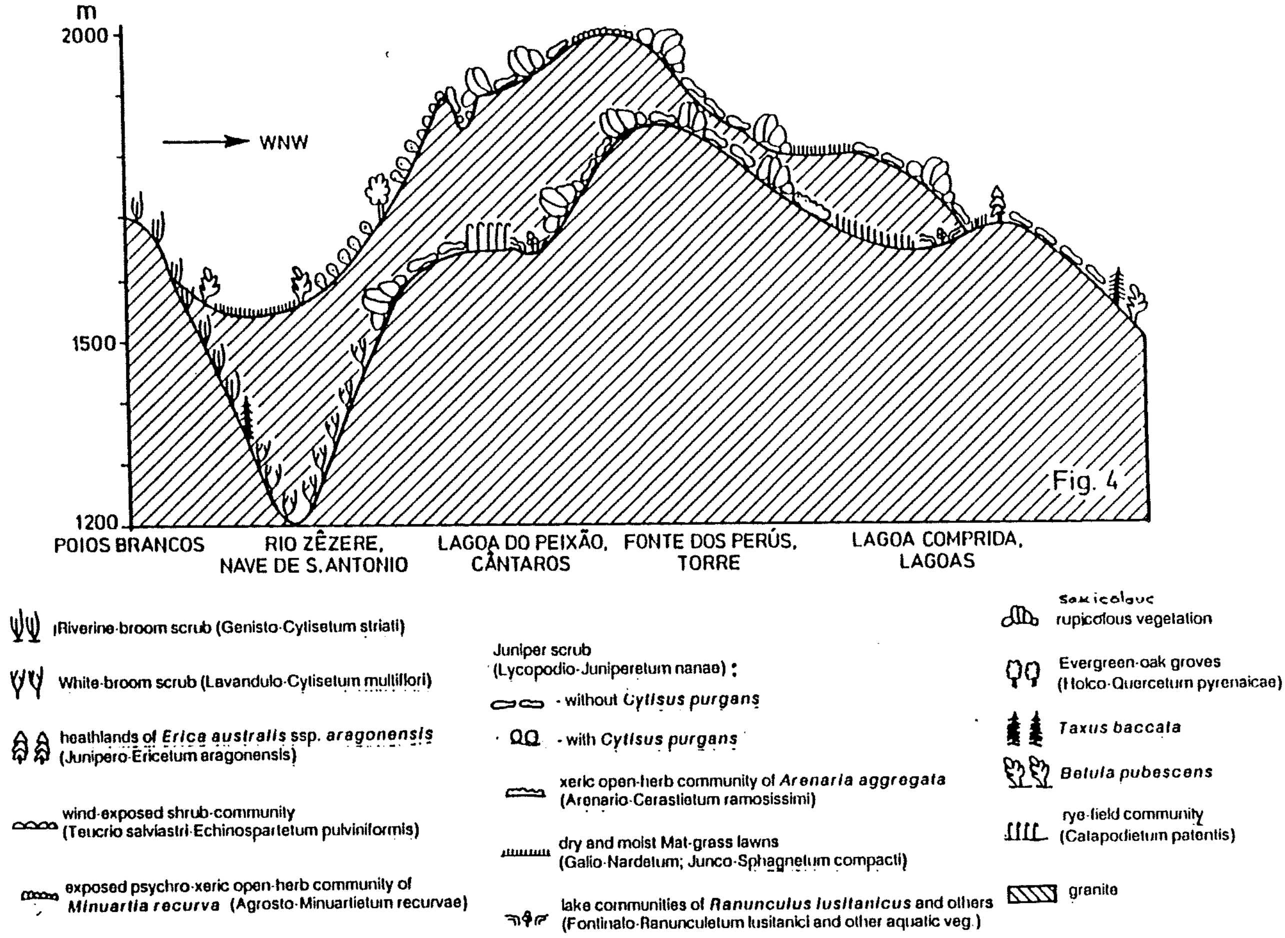


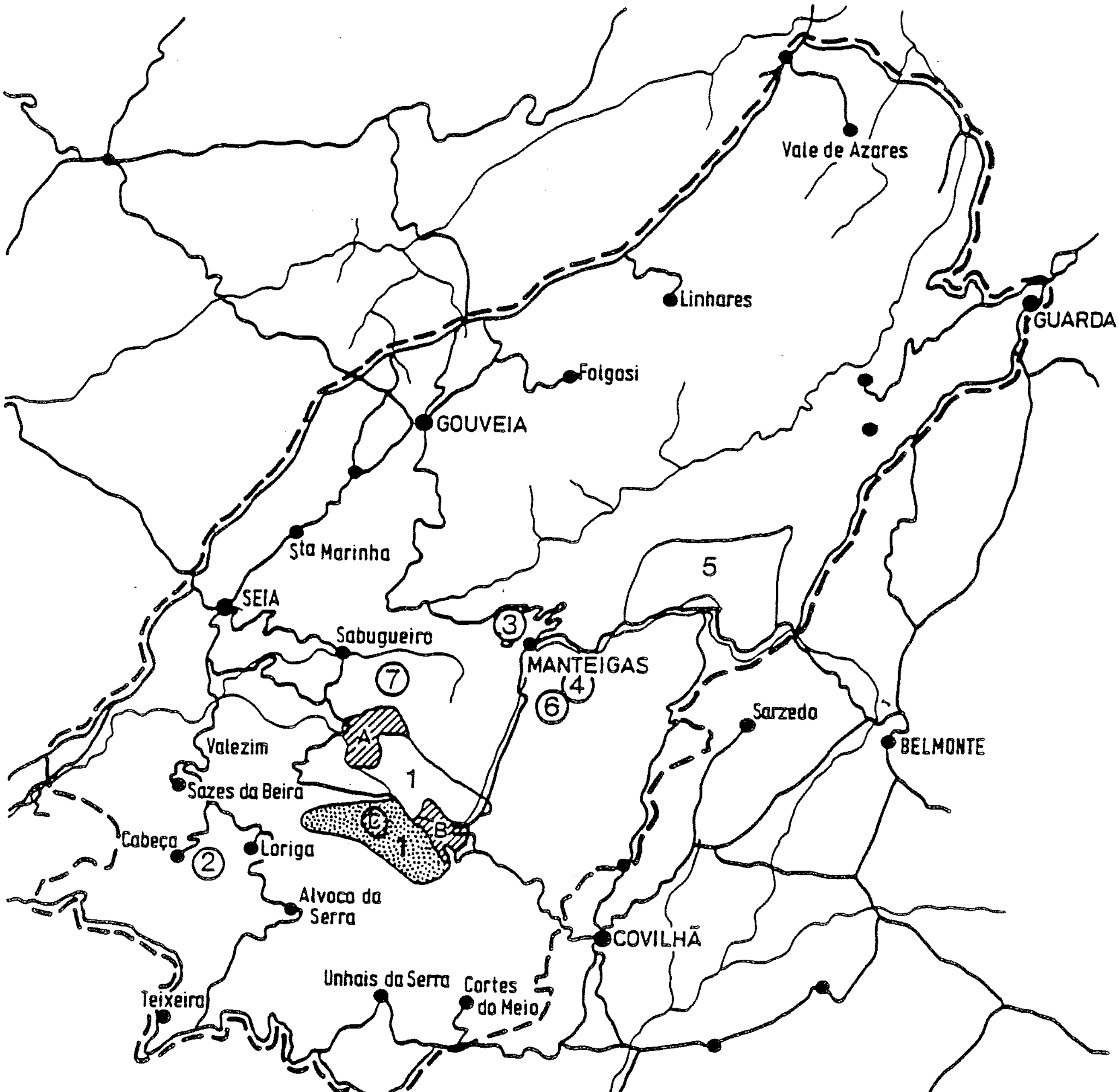
m
1000
500
SSE
Fig. 1
RIO ZÊZERE
(SW OF VALHELHAS)
CABEÇA ALTA
Evergreen oaks
Quercus rotundifolia
Pinus pinaster
arable fields
schist-grauwacke complex



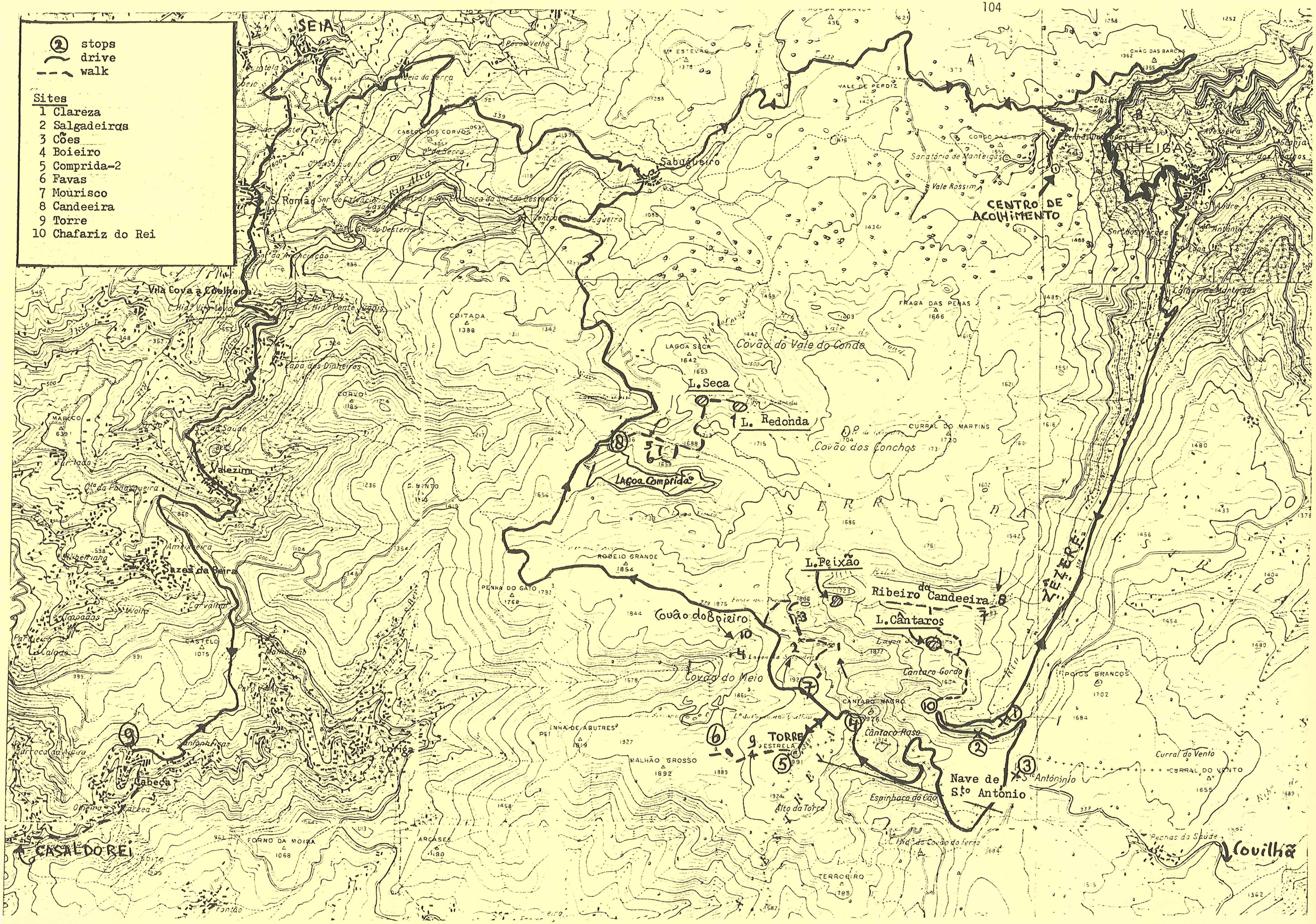
m
1000
500
NNW
Fig. 2
FORNO DA MOURA
RIBEIRA DE LORIGA
CASTELO
Evergreen oaks
Quercus rotundifolia
Pinus pinaster
Portuguese laurel cherry
Prunus lusitanica
schist-grauwacke complex
grey wacke

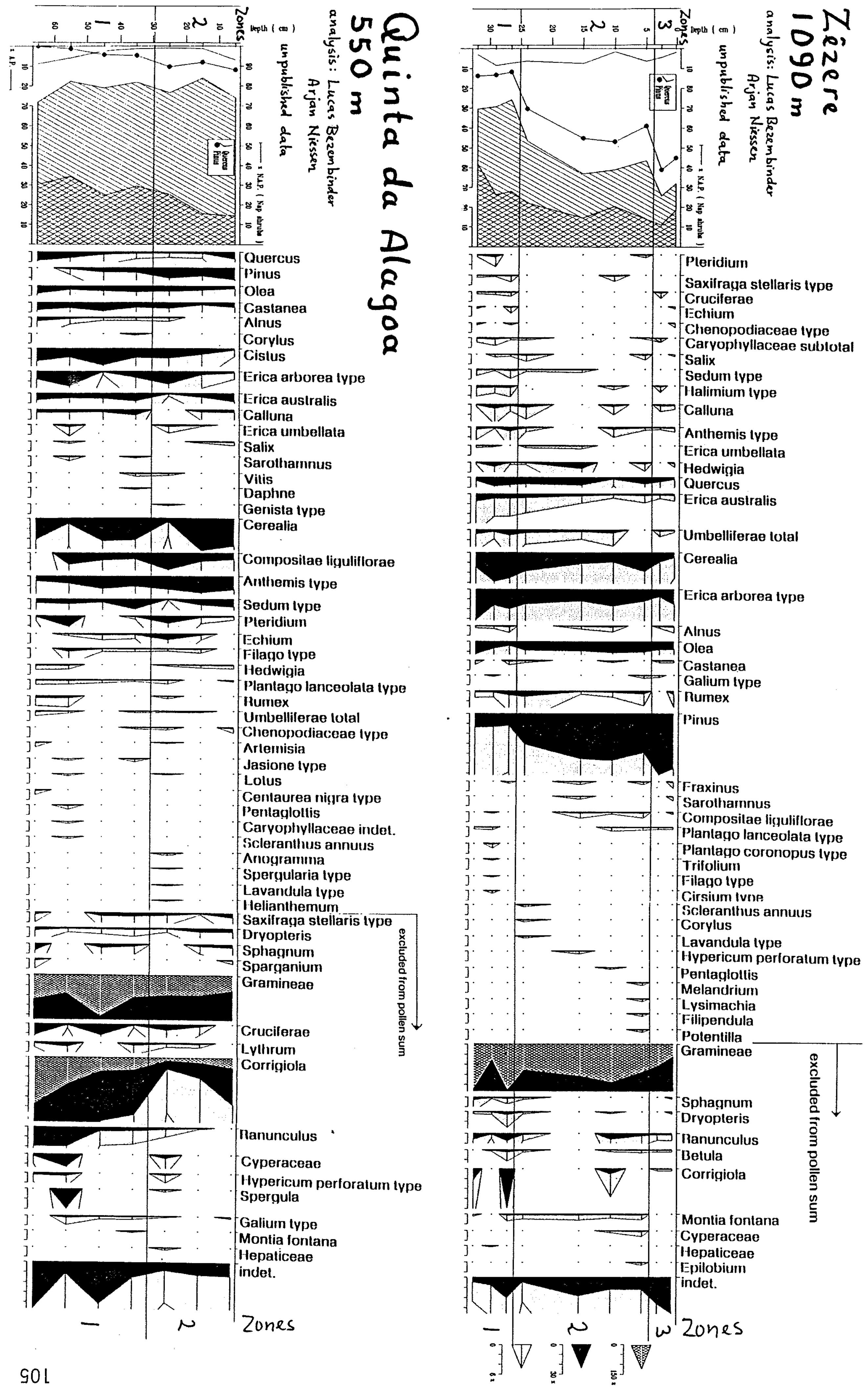

m
1400
1000
600
NW
Carvalheira
Souto do Conselho
Fig. 3
POÇO DO INFERNO
RIO ZÊZERE, MANTEIGAS
PENHAS DOURADAS
MONDEGUINHO (source of Mondego)
Evergreen-oak groves (Holco-Quercetum pyrenaicae)
heathlands of Erica australis ssp. aragonensis (Junipero-Ericetum aragonensis)
Rock-rose fields of Halimium alyssoides
rupicolous vegetation
debris slopes
chestnut groves Castanea sativa
Pinus pinaster
Pseudotsuga menziesii
Olive trees (Olea europea)
rye-field community (Calapodietum patentis)
arable fields
schist-greywacke complex
granite


m
2000
1500
1200
WNW
Fig. 4
POIOS BRANCOS
RIO ZÊZERE, NAVE DE S. ANTONIO
LAGOA DO PEIXÃO, CÂNTAROS
FONTE DOS PERÚS, TORRE
LAGOA COMPRIDA, LAGOAS
Riverine-broom scrub (Genisto-Cytisetum striati)
White-broom scrub (Lavandulo-Cytisetum multiflori)
heathlands of Erica australis ssp. aragonensis (Junipero-Ericetum aragonensis)
wind-exposed shrub-community (Teucrio salviastri-Echinospartetum pulviniformis)
exposed psychro-xeric open-herb community of Minuartia recurva (Agrosto-Minuartietum recurvae)
Juniper scrub (Lycopodio-Juniperetum nanae):
- without Cytisus purgans
- with Cytisus purgans
xeric open-herb community of Arenaria aggregata (Arenario-Cerastietum ramosissimi)
dry and moist Mat-grass lawns (Galio-Nardetum; Junco-Sphagnetum compacti)
lake communities of Ranunculus lusitanicus and others (Fontinalo-Ranunculetum lusitanici and other aquatic veg.)
saxicolous
rupicolous vegetation
Evergreen-oak groves (Holco-Quercetum pyrenaicae)
Taxus baccata
Betula pubescens
rye-field community (Calapodietum patentis)
granite

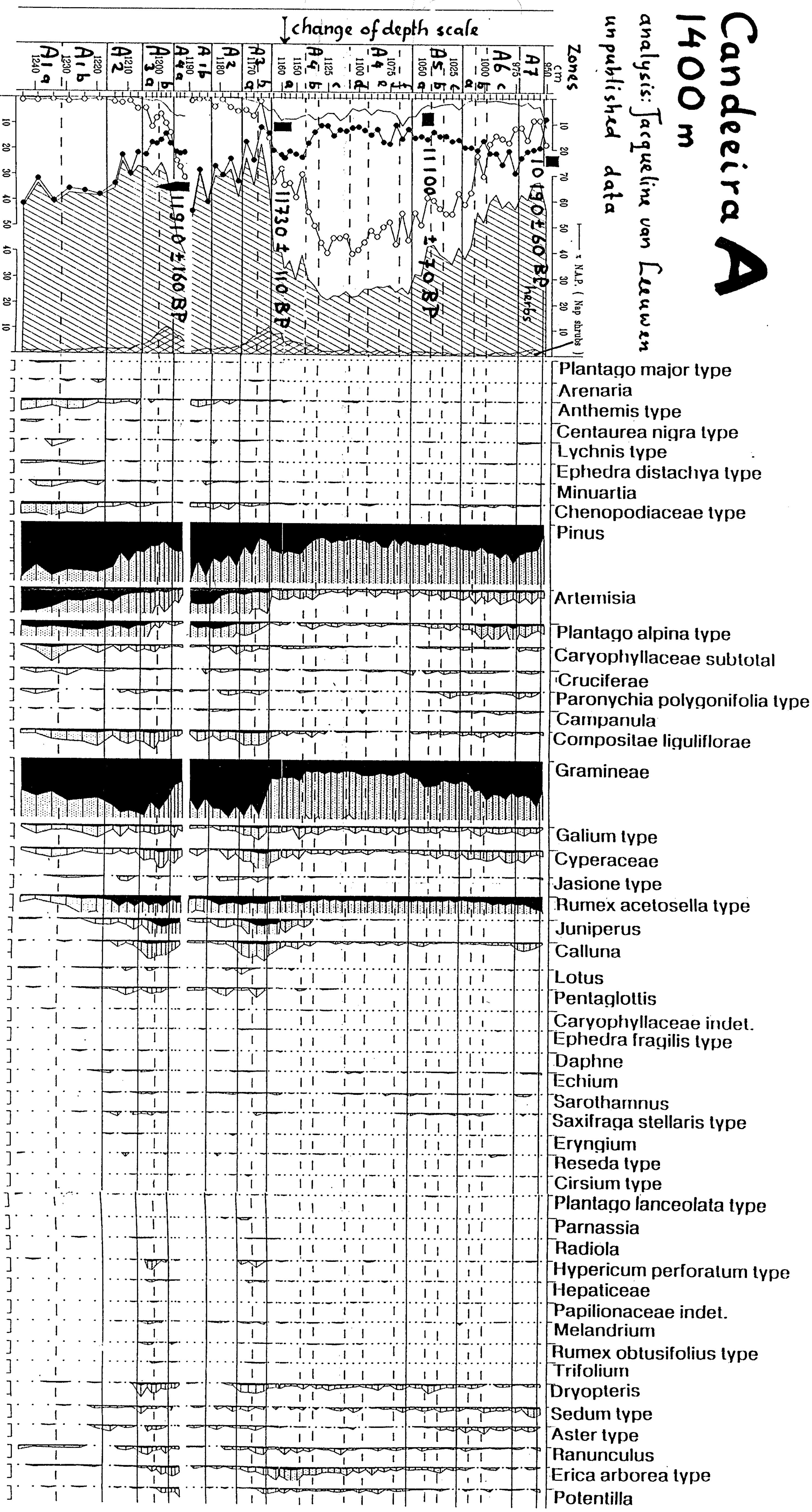


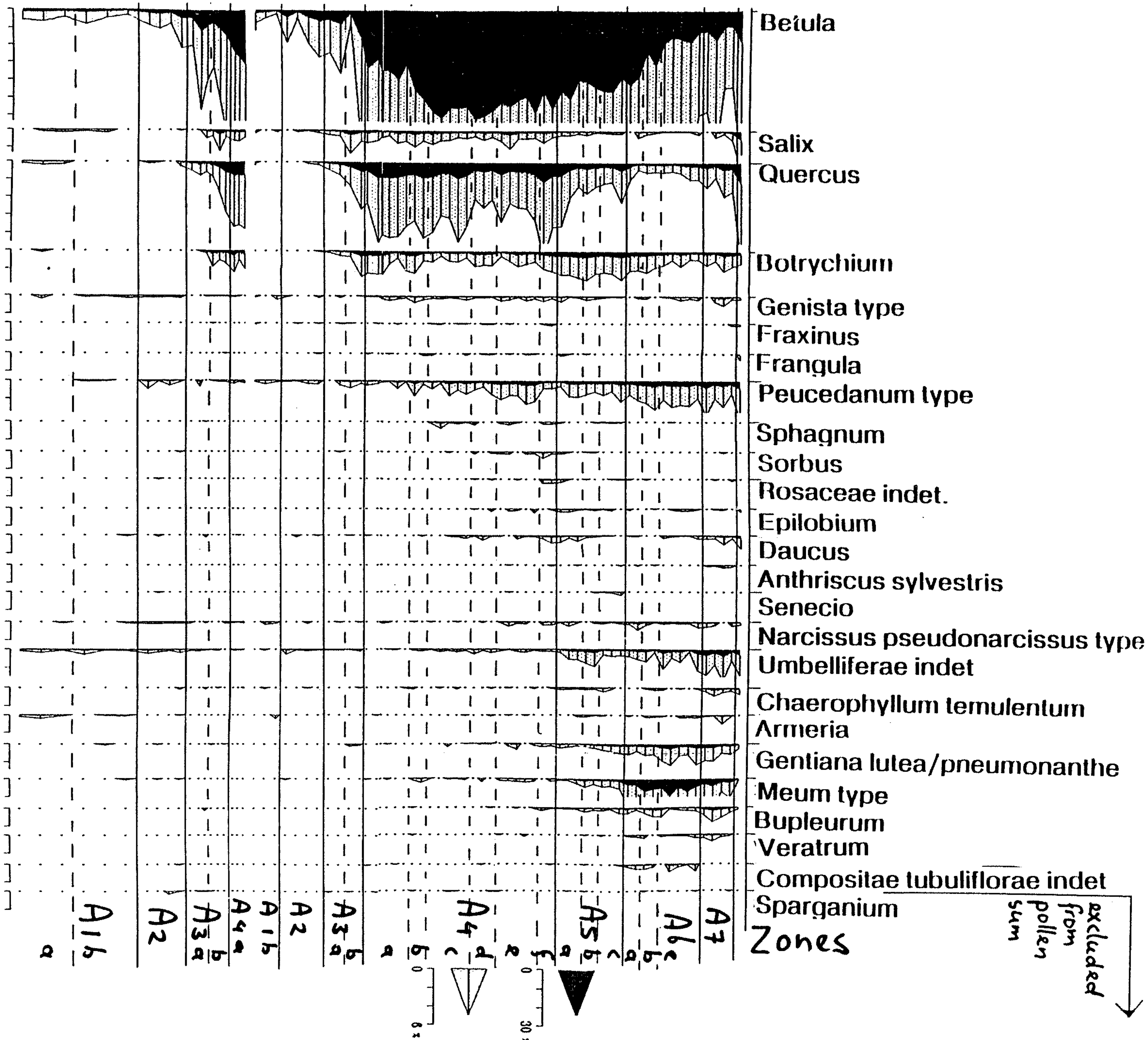
Strict Botanical Reserves


stops
drive
walk
Sites
1 Clareza
2 Salgadeiras
3 Cões
4 Boieiro
5 Comprida-2
6 Favas
7 Mourisco
8 Candeeira
9 Torre
10 Chafariz do Rei
SEIA
Sabugueiro
MANTEIGAS
CENTRO DE ACOLHIMENTO
Vila Cova à Coelheira
Valezim
Sazes da Beira
Loriga
Cabeça
CASAL DO REI
L. Seca
L. Redonda
Lagoa Comprida
Covão dos Conchos
Covão do Vale do Conde
L. Peixão
Ribeiro da Candeeira
L. Cântaros
Covão do Boieiro
Covão do Meio
TORRE
Nave de Sto António
ZEZERE
Covilhã

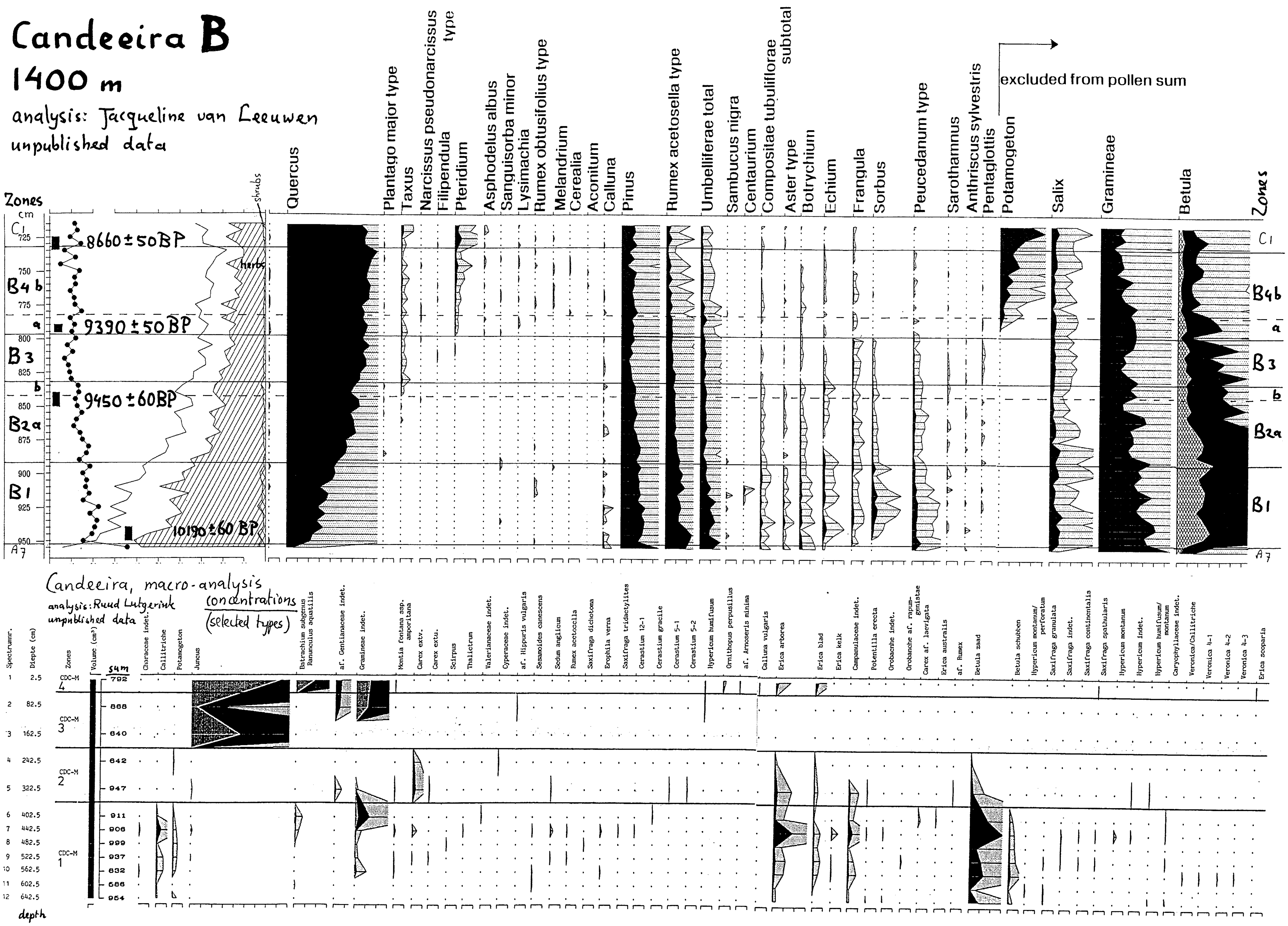


Quinta da Alagoa
550 m
analysis: Lucas Bezembinder
Arjan Nissen
unpublished data
Depth (cm)
Zones
Quercus
Pinus
Quercus
Pinus
Olea
Castanea
Alnus
Corylus
Cistus
Erica arborea type
Erica australis
Calluna
Erica umbellata
Salix
Sarothamnus
Vitis
Daphne
Genista type
Cerealia
Compositae liguliflorae
Anthemis type
Sedum type
Pteridium
Echium
Filago type
Hedwigia
Plantago lanceolata type
Rumex
Umbelliferae total
Chenopodiaceae type
Artemisia
Jasione type
Lotus
Centaurea nigra type
Pentaglottis
Caryophyllaceae indet.
Scleranthus annuus
Anogramma
Spergularia type
Lavandula type
Helianthemum
Saxifraga stellaris type
Dryopteris
Sphagnum
Sparganium
Gramineae
excluded from pollen sum
Cruciferae
Lythrum
Corrigiola
Ranunculus
Cyperaceae
Hypericum perforatum type
Spergula
Galium type
Montia fontana
Hepaticeae
indet.
1
2
Zones
Zêzere
1090 m
analysis: Lucas Bezembinder
Arjan Nissen
unpublished data
Depth (cm)
Zones
Quercus
Pinus
Pteridium
Saxifraga stellaris type
Cruciferae
Echium
Chenopodiaceae type
Caryophyllaceae subtotal
Salix
Sedum type
Halimium type
Calluna
Anthemis type
Erica umbellata
Hedwigia
Quercus
Erica australis
Umbelliferae total
Cerealia
Erica arborea type
Alnus
Olea
Castanea
Galium type
Rumex
Pinus
Fraxinus
Sarothamnus
Compositae liguliflorae
Plantago lanceolata type
Plantago coronopus type
Trifolium
Filago type
Cirsium type
Scleranthus annuus
Corylus
Lavandula type
Hypericum perforatum type
Pentaglottis
Melandrium
Lysimachia
Filipendula
Potentilla
Gramineae
excluded from pollen sum
Sphagnum
Dryopteris
Ranunculus
Betula
Corrigiola
Montia fontana
Cyperaceae
Hepaticeae
Epilobium
indet.
1
2
3
Zones

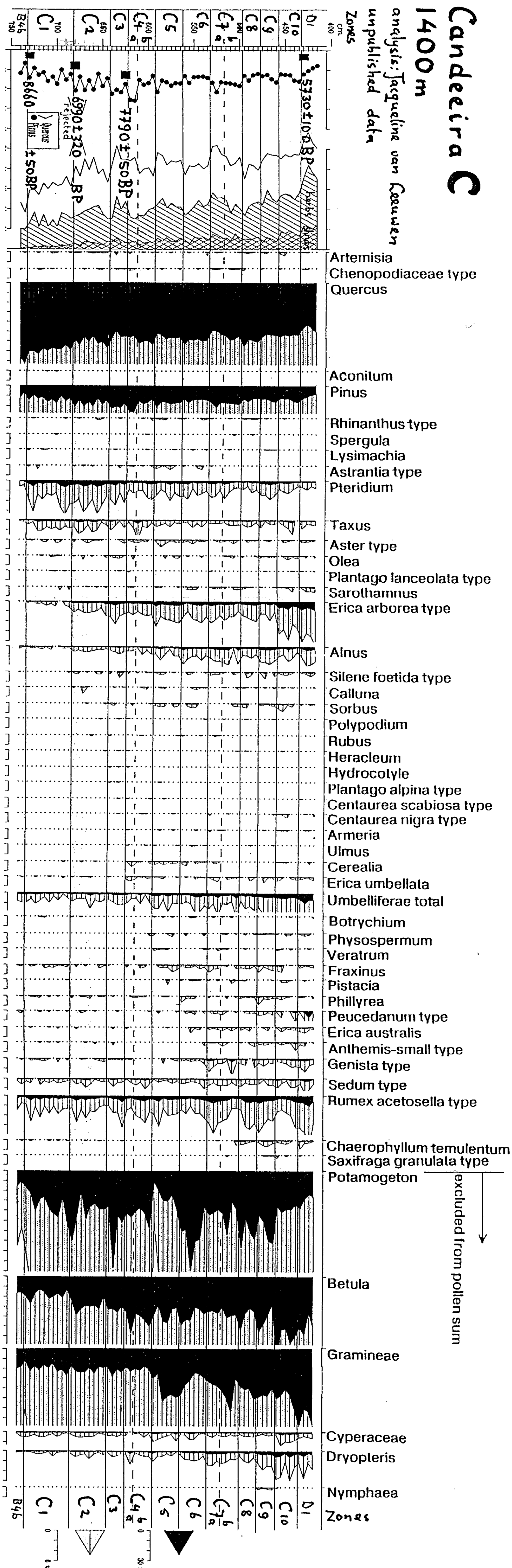

Candeeira A
1400 m
analysis: Jacqueline van Leeuwen
unpublished data
change of depth scale
Zones
11910 ± 160 BP
11730 ± 110 BP
11100 ± 70 BP
10190 ± 60 BP
herbs
N.A.P. (Nap shrubs)
A.P.
Plantago major type
Arenaria
Anthemis type
Centaurea nigra type
Lychnis type
Ephedra distachya type
Minuartia
Chenopodiaceae type
Pinus
Artemisia
Plantago alpina type
Caryophyllaceae subtotal
Cruciferae
Paronychia polygonifolia type
Campanula
Compositae liguliflorae
Gramineae
Galium type
Cyperaceae
Jasione type
Rumex acetosella type
Juniperus
Calluna
Lotus
Pentaglottis
Caryophyllaceae indet.
Ephedra fragilis type
Daphne
Echium
Sarothamnus
Saxifraga stellaris type
Eryngium
Reseda type
Cirsium type
Plantago lanceolata type
Parnassia
Radiola
Hypericum perforatum type
Hepaticeae
Papilionaceae indet.
Melandrium
Rumex obtusifolius type
Trifolium
Dryopteris
Sedum type
Aster type
Ranunculus
Erica arborea type
Potentilla

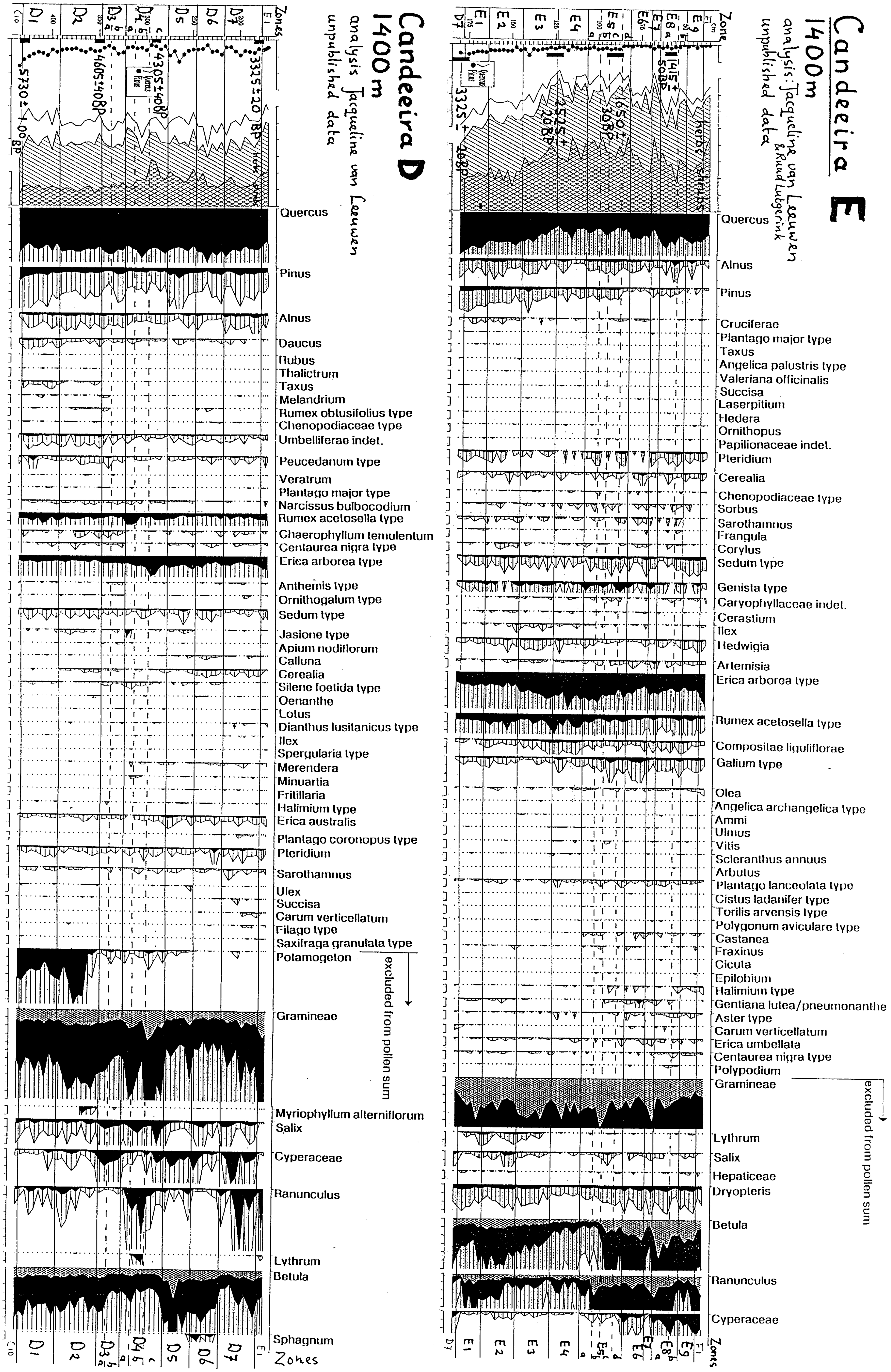

Betula
Salix
Quercus
Botrychium
Genista type
Fraxinus
Frangula
Peucedanum type
Sphagnum
Sorbus
Rosaceae indet.
Epilobium
Daucus
Anthriscus sylvestris
Senecio
Narcissus pseudonarcissus type
Umbelliferae indet
Chaerophyllum temulentum
Armeria
Gentiana lutea/pneumonanthe
Meum type
Bupleurum
Veratrum
Compositae tubuliflorae indet
Sparganium
excluded from pollen sum
A1b
A2
A3
A4
A5
A6
A7
Zones
30%

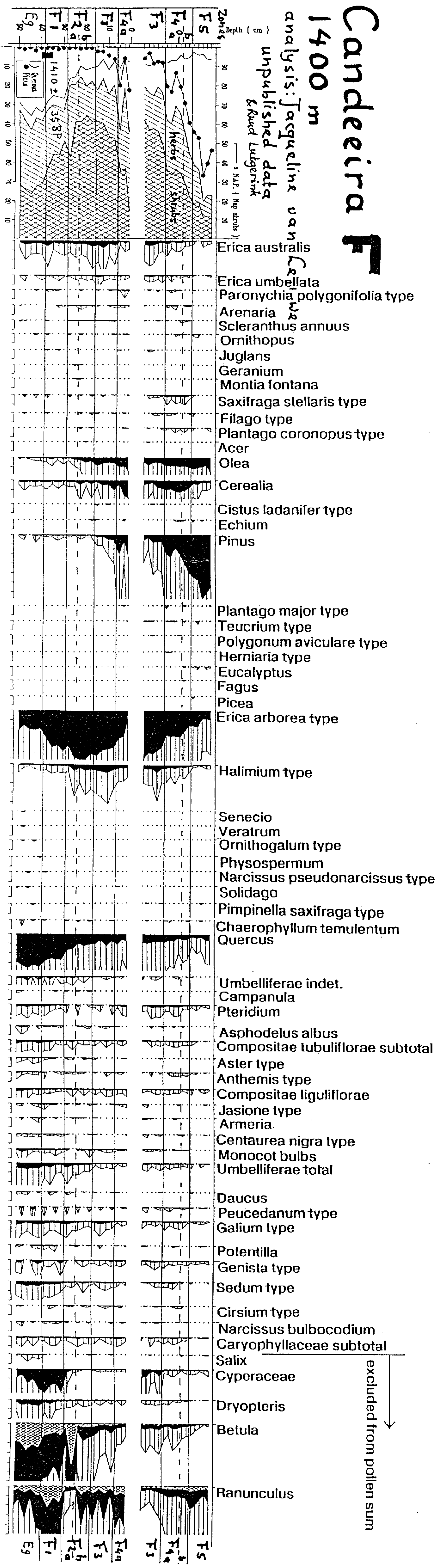
106/107

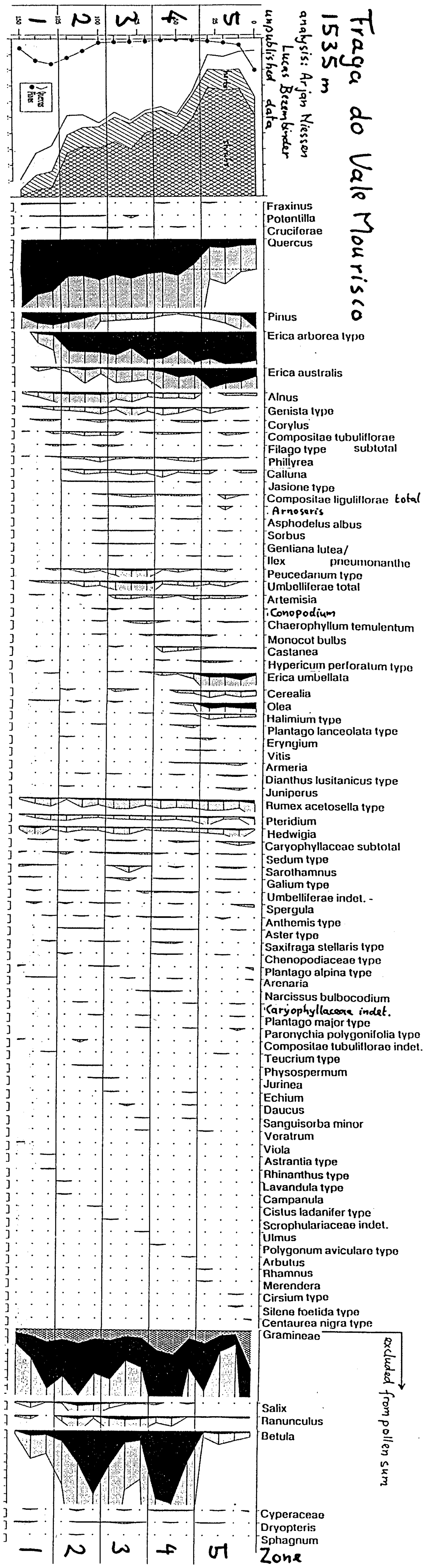


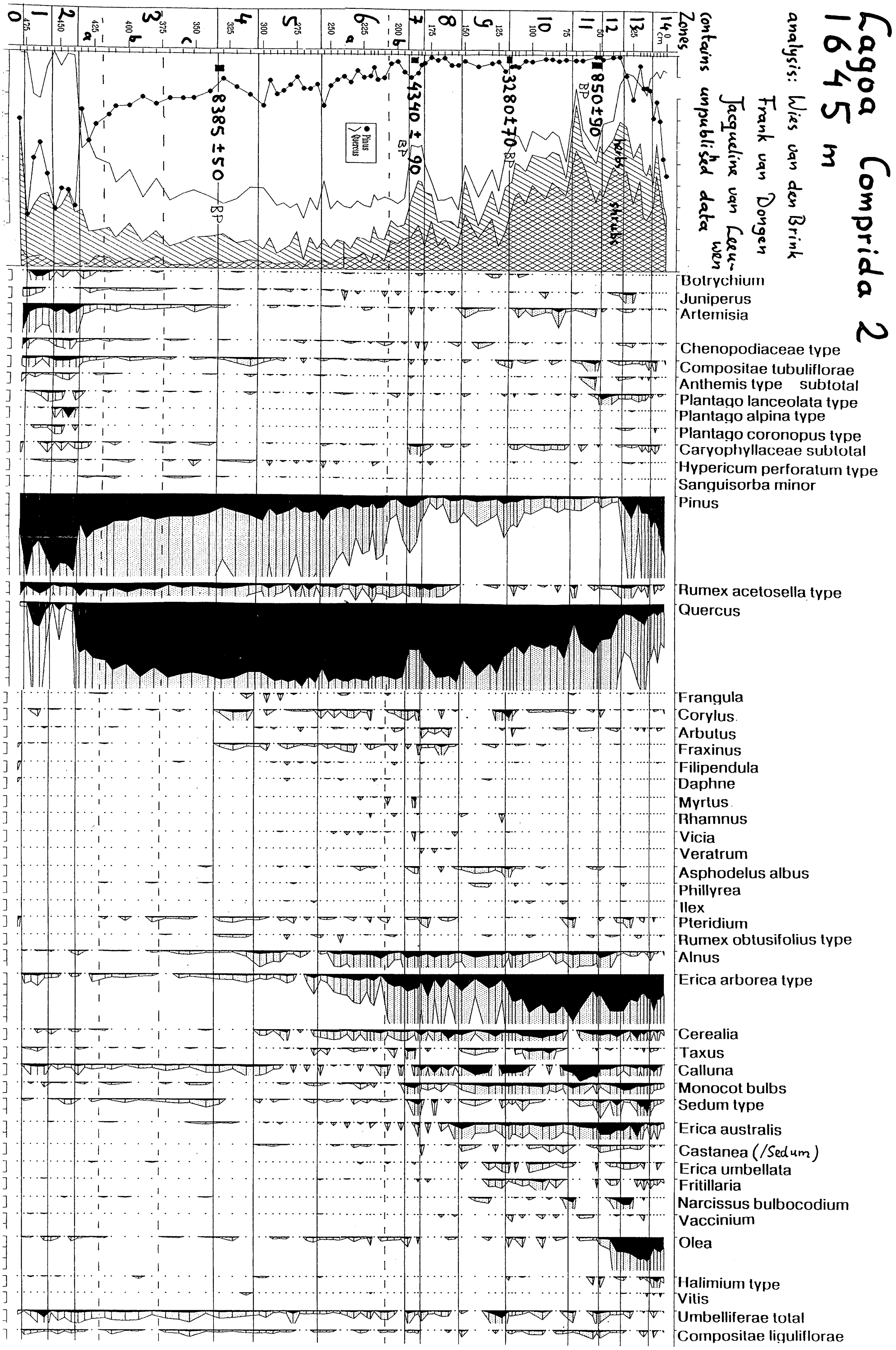
Candeeira B
1400 m
analysis: Jacqueline van Leeuwen
unpublished data
Zones
cm
C1
B4 b
a
B3
b
B2a
B1
A7
8660±50BP
9390±50BP
9450±60BP
10190±60 BP
herbs
shrubs
Quercus
Plantago major type
Taxus
Narcissus pseudonarcissus type
Filipendula
Pteridium
Asphodelus albus
Sanguisorba minor
Lysimachia
Rumex obtusifolius type
Melandrium
Cerealia
Aconitum
Calluna
Pinus
Rumex acetosella type
Umbelliferae total
Sambucus nigra
Centaurium
Compositae tubuliflorae subtotal
Aster type
Botrychium
Echium
Frangula
Sorbus
Peucedanum type
Sarothamnus
Anthriscus sylvestris
Pentaglottis
excluded from pollen sum
Potamogeton
Salix
Gramineae
Betula
Zones
Candeeira, macro-analysis
analysis: Ruud Lutgerink
unpublished data
concentrations
(selected types)
Spectrumnr.
Diepte (cm)
Zones
Volume (cm³)
sum
CDC-M 4
CDC-M 3
CDC-M 2
CDC-M 1
depth
Characeae indet.
Callitriche
Potamogeton
Juncus
Batrachium subgenus Ranunculus aquatilis
af. Gentianaceae indet.
Gramineae indet.
Montia fontana ssp. amporitana
Carex extv.
Carex extu.
Scirpus
Thalictrum
Valerianaceae indet.
Cyperaceae indet.
af. Hippuris vulgaris
Sesamoides canescens
Sedum anglicum
Rumex acetosella
Saxifraga dichotoma
Erophila verna
Saxifraga tridactylites
Cerastium 12-1
Cerastium gracile
Cerastium 5-1
Cerastium 5-2
Hypericum humifusum
Ornithopus perpusillus
af. Arnoseris minima
Calluna vulgaris
Erica arborea
Erica blad
Erica kelk
Campanulaceae indet.
Potentilla erecta
Orobanche indet.
Orobanche af. rapum-genistae
Carex af. laevigata
Erica australis
af. Rumex
Betula zaad
Betula schubben
Hypericum montanum/ perforatum
Saxifraga granulata
Saxifraga indet.
Saxifraga continentalis
Saxifraga spathularis
Hypericum montanum
Hypericum indet.
Hypericum humifusum/ montanum
Caryophyllaceae indet.
Veronica/Callitriche
Veronica 4-1
Veronica 4-2
Veronica 4-3
Erica scoparia


Candeeira C
1400m
analysis: Jacqueline van Leeuwen
unpublished data
Zones
cm.
Quercus
Pinus
Herbs
Shrubs
8660 ± 50BP
6990 ± 320 BP
rejected
7790 ± 50BP
5730 ± 100BP
Artemisia
Chenopodiaceae type
Quercus
Aconitum
Pinus
Rhinanthus type
Spergula
Lysimachia
Astrantia type
Pteridium
Taxus
Aster type
Olea
Plantago lanceolata type
Sarothamnus
Erica arborea type
Alnus
Silene foetida type
Calluna
Sorbus
Polypodium
Rubus
Heracleum
Hydrocotyle
Plantago alpina type
Centaurea scabiosa type
Centaurea nigra type
Armeria
Ulmus
Cerealia
Erica umbellata
Umbelliferae total
Botrychium
Physospermum
Veratrum
Fraxinus
Pistacia
Phillyrea
Peucedanum type
Erica australis
Anthemis-small type
Genista type
Sedum type
Rumex acetosella type
Chaerophyllum temulentum
Saxifraga granulata type
Potamogeton
excluded from pollen sum
Betula
Gramineae
Cyperaceae
Dryopteris
Nymphaea
B4b C1 C2 C3 C4a C4b C5 C6 C7a C7b C8 C9 C10 D1
Zones

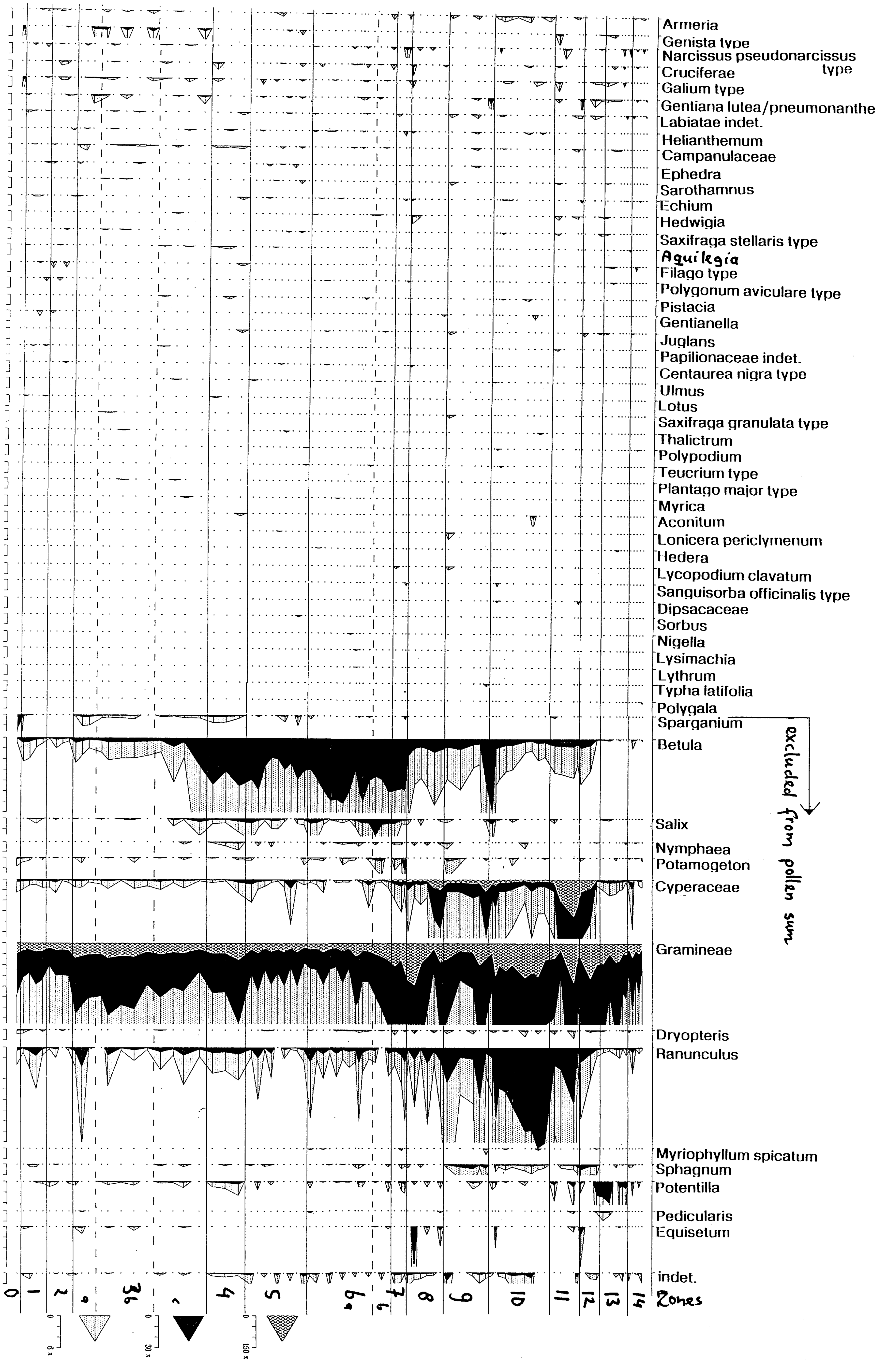

Candeeira D
1400 m
analysis Jaqueline van Leeuwen
unpublished data
Zones
D1 D2 D3 D4 D5 D6 D7 E1
5730±100 BP
4605±40 BP
4305±40 BP
3325±20 BP
Quercus
Pinus
herbs shrubs
Quercus
Pinus
Alnus
Daucus
Rubus
Thalictrum
Taxus
Melandrium
Rumex obtusifolius type
Chenopodiaceae type
Umbelliferae indet.
Peucedanum type
Veratrum
Plantago major type
Narcissus bulbocodium
Rumex acetosella type
Chaerophyllum temulentum
Centaurea nigra type
Erica arborea type
Anthemis type
Ornithogalum type
Sedum type
Jasione type
Apium nodiflorum
Calluna
Cerealia
Silene foetida type
Oenanthe
Lotus
Dianthus lusitanicus type
Ilex
Spergularia type
Merendera
Minuartia
Fritillaria
Halimium type
Erica australis
Plantago coronopus type
Pteridium
Sarothamnus
Ulex
Succisa
Carum verticellatum
Filago type
Saxifraga granulata type
Potamogeton
excluded from pollen sum
Gramineae
Myriophyllum alterniflorum
Salix
Cyperaceae
Ranunculus
Lythrum
Betula
Sphagnum
Candeeira E
1400 m
analysis: Jaqueline van Leeuwen & Ruud Lutgerink
unpublished data
Zone
E1 E2 E3 E4 E5 E6 E7 E8 E9 F1
3325±20 BP
2525±20 BP
1650±30 BP
1415±50 BP
herbs shrubs
Quercus
Alnus
Pinus
Cruciferae
Plantago major type
Taxus
Angelica palustris type
Valeriana officinalis
Succisa
Laserpitium
Hedera
Ornithopus
Papilionaceae indet.
Pteridium
Cerealia
Chenopodiaceae type
Sorbus
Sarothamnus
Frangula
Corylus
Sedum type
Genista type
Caryophyllaceae indet.
Cerastium
Ilex
Hedwigia
Artemisia
Erica arborea type
Rumex acetosella type
Compositae liguliflorae
Galium type
Olea
Angelica archangelica type
Ammi
Ulmus
Vitis
Scleranthus annuus
Arbutus
Plantago lanceolata type
Cistus ladanifer type
Torilis arvensis type
Polygonum aviculare type
Castanea
Fraxinus
Cicuta
Epilobium
Halimium type
Gentiana lutea/pneumonanthe
Aster type
Carum verticellatum
Erica umbellata
Centaurea nigra type
Polypodium
Gramineae
excluded from pollen sum
Lythrum
Salix
Hepaticeae
Dryopteris
Betula
Ranunculus
Cyperaceae

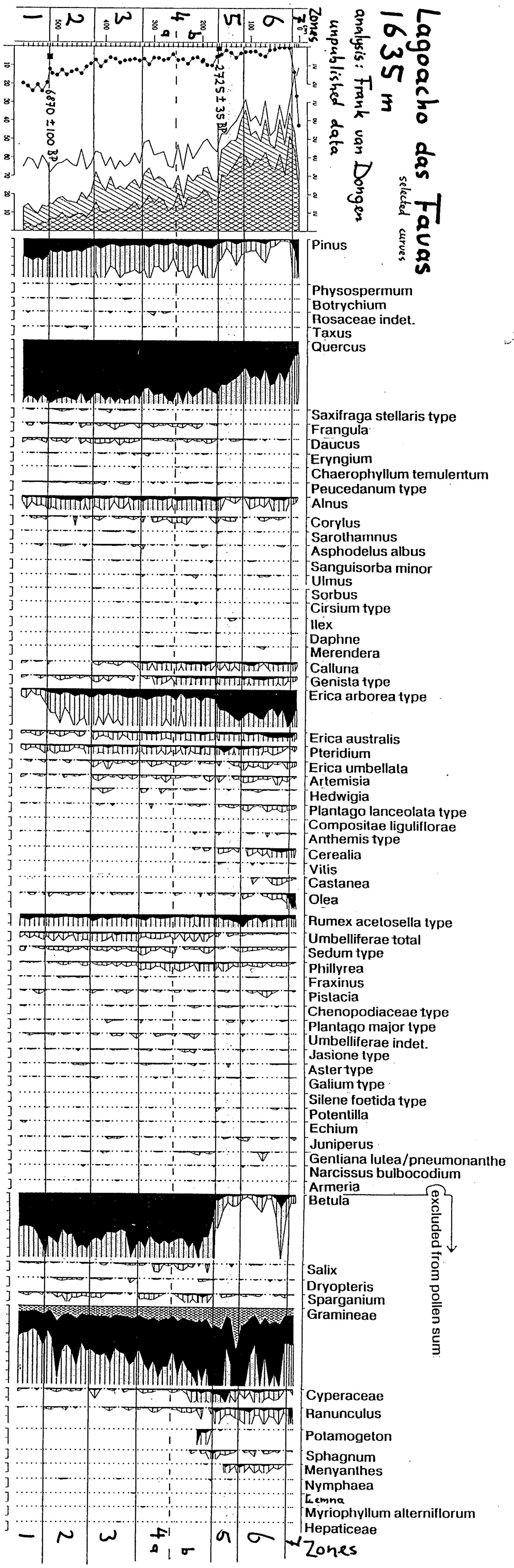

Candeeira F
1400 m
analysis: Jacqueline van Leeuwen & Ruud Lutgerink
unpublished data
Zones
Depth (cm)
1410 ± 35 BP
Quercus
Pinus
herbs
shrubs
± N.A.P. (Nap shrubs)
Erica australis
Erica umbellata
Paronychia polygonifolia type
Arenaria
Scleranthus annuus
Ornithopus
Juglans
Geranium
Montia fontana
Saxifraga stellaris type
Filago type
Plantago coronopus type
Acer
Olea
Cerealia
Cistus ladanifer type
Echium
Pinus
Plantago major type
Teucrium type
Polygonum aviculare type
Herniaria type
Eucalyptus
Fagus
Picea
Erica arborea type
Halimium type
Senecio
Veratrum
Ornithogalum type
Physospermum
Narcissus pseudonarcissus type
Solidago
Pimpinella saxifraga type
Chaerophyllum temulentum
Quercus
Umbelliferae indet.
Campanula
Pteridium
Asphodelus albus
Compositae tubuliflorae subtotal
Aster type
Anthemis type
Compositae liguliflorae
Jasione type
Armeria
Centaurea nigra type
Monocot bulbs
Umbelliferae total
Daucus
Peucedanum type
Galium type
Potentilla
Genista type
Sedum type
Cirsium type
Narcissus bulbocodium
Caryophyllaceae subtotal
Salix
Cyperaceae
Dryopteris
Betula
Ranunculus
excluded from pollen sum
E9 F1 F2a F3 F4a F3 F4a F5


Fraga do Vale Mourisco
1535 m
analysis: Arjan Niessen
Lucas Bremmbinder
unpublished data
1 2 3 4 5
Quercus
Pinus
Fraxinus
Potentilla
Cruciferae
Quercus
Pinus
Erica arborea type
Erica australis
Alnus
Genista type
Corylus
Compositae tubuliflorae subtotal
Filago type
Phillyrea
Calluna
Jasione type
Compositae liguliflorae total
Arnoseris
Asphodelus albus
Sorbus
Gentiana lutea/pneumonanthe
Ilex
Peucedanum type
Umbelliferae total
Artemisia
Conopodium
Chaerophyllum temulentum
Monocot bulbs
Castanea
Hypericum perforatum type
Erica umbellata
Cerealia
Olea
Halimium type
Plantago lanceolata type
Eryngium
Vitis
Armeria
Dianthus lusitanicus type
Juniperus
Rumex acetosella type
Pteridium
Hedwigia
Caryophyllaceae subtotal
Sedum type
Sarothamnus
Galium type
Umbelliferae indet. -
Spergula
Anthemis type
Aster type
Saxifraga stellaris type
Chenopodiaceae type
Plantago alpina type
Arenaria
Narcissus bulbocodium
Caryophyllaceae indet.
Plantago major type
Paronychia polygonifolia type
Compositae tubuliflorae indet.
Teucrium type
Physospermum
Jurinea
Echium
Daucus
Sanguisorba minor
Veratrum
Viola
Astrantia type
Rhinanthus type
Lavandula type
Campanula
Cistus ladanifer type
Scrophulariaceae indet.
Ulmus
Polygonum aviculare type
Arbutus
Rhamnus
Merendera
Cirsium type
Silene foetida type
Centaurea nigra type
Gramineae
excluded from pollen sum
Salix
Ranunculus
Betula
Cyperaceae
Dryopteris
Sphagnum
1 2 3 4 5 Zone

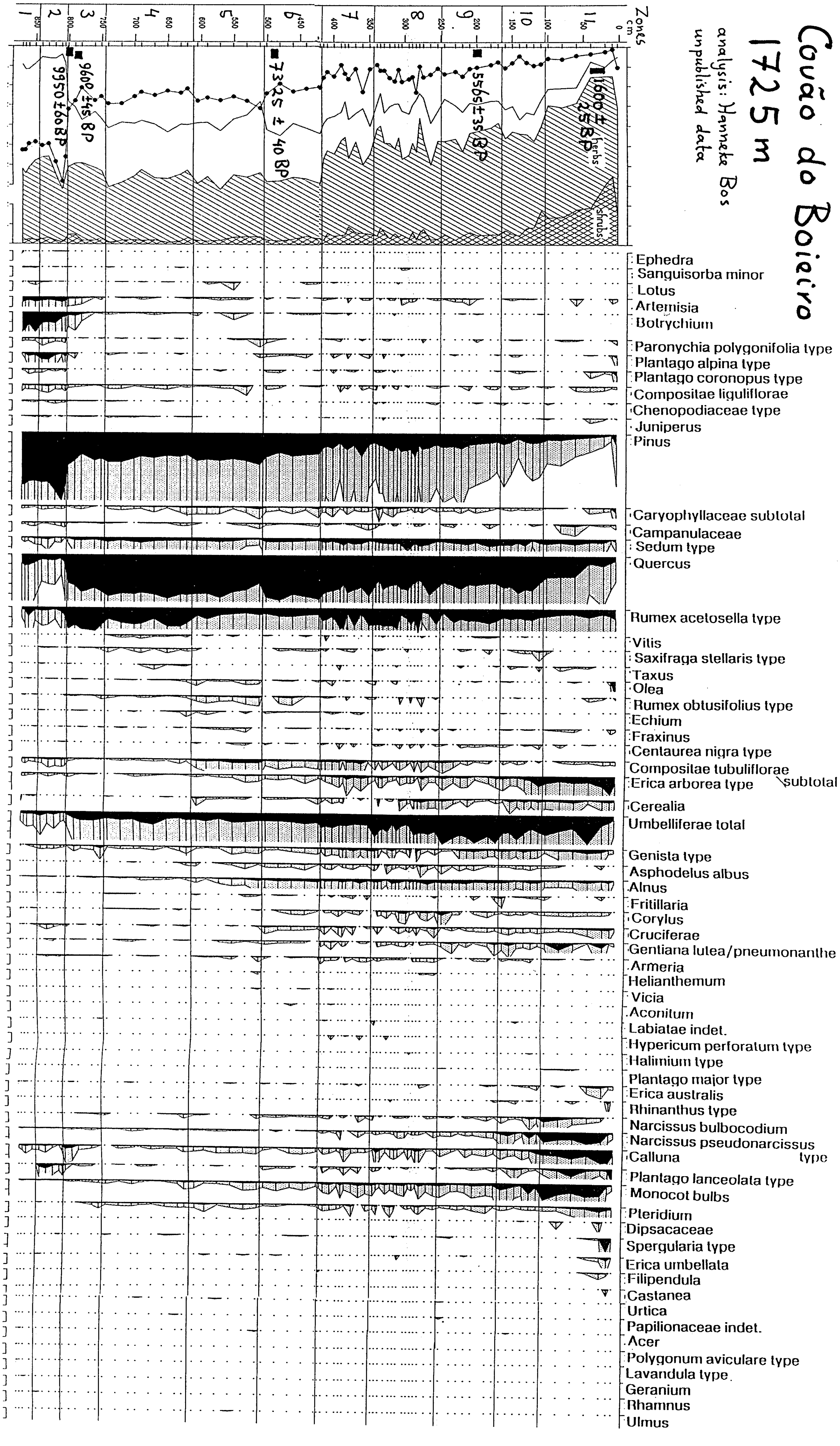


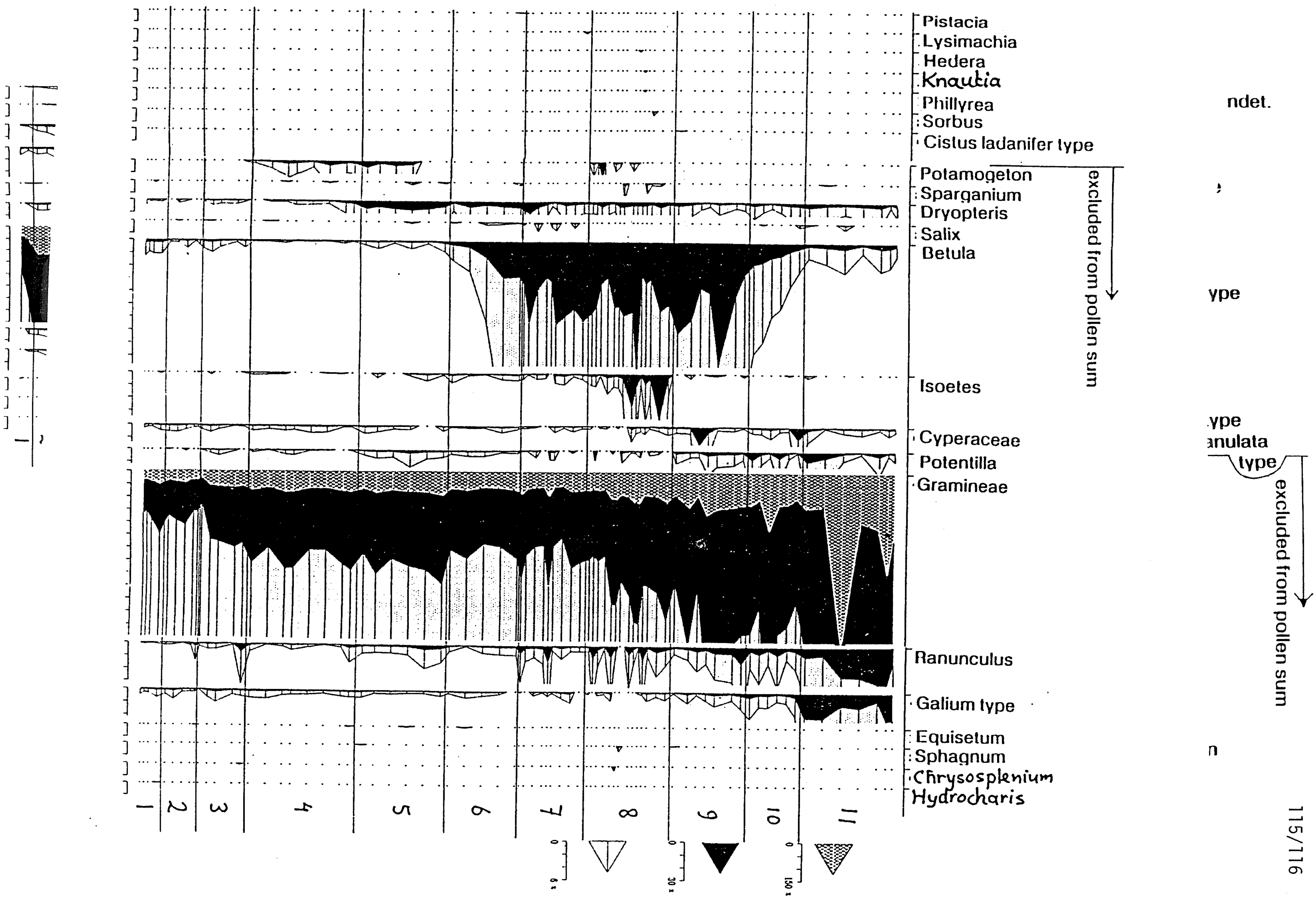
Lagoa Comprida 2
1645 m
analysis: Wies van den Brink
Frank van Dongen
Jacqueline van Leeuwen
contains unpublished data
Zones
8385 ± 50 BP
4340 ± 90 BP
3280 ± 70 BP
850 ± 90 BP
Pinus
Quercus
herbs
shrubs
Botrychium
Juniperus
Artemisia
Chenopodiaceae type
Compositae tubuliflorae
Anthemis type subtotal
Plantago lanceolata type
Plantago alpina type
Plantago coronopus type
Caryophyllaceae subtotal
Hypericum perforatum type
Sanguisorba minor
Pinus
Rumex acetosella type
Quercus
Frangula
Corylus
Arbutus
Fraxinus
Filipendula
Daphne
Myrtus
Rhamnus
Vicia
Veratrum
Asphodelus albus
Phillyrea
Ilex
Pteridium
Rumex obtusifolius type
Alnus
Erica arborea type
Cerealia
Taxus
Calluna
Monocot bulbs
Sedum type
Erica australis
Castanea (/Sedum)
Erica umbellata
Fritillaria
Narcissus bulbocodium
Vaccinium
Olea
Halimium type
Vitis
Umbelliferae total
Compositae liguliflorae


Armeria
Genista type
Narcissus pseudonarcissus type
Cruciferae
Galium type
Gentiana lutea/pneumonanthe
Labiatae indet.
Helianthemum
Campanulaceae
Ephedra
Sarothamnus
Echium
Hedwigia
Saxifraga stellaris type
Aquilegia
Filago type
Polygonum aviculare type
Pistacia
Gentianella
Juglans
Papilionaceae indet.
Centaurea nigra type
Ulmus
Lotus
Saxifraga granulata type
Thalictrum
Polypodium
Teucrium type
Plantago major type
Myrica
Aconitum
Lonicera periclymenum
Hedera
Lycopodium clavatum
Sanguisorba officinalis type
Dipsacaceae
Sorbus
Nigella
Lysimachia
Lythrum
Typha latifolia
Polygala
Sparganium
Betula
Salix
Nymphaea
Potamogeton
Cyperaceae
Gramineae
excluded from pollen sum
Dryopteris
Ranunculus
Myriophyllum spicatum
Sphagnum
Potentilla
Pedicularis
Equisetum
indet.
0 1 2 3b 4 5 6a 6b 7 8 9 10 11 12 13 14 Zones
6 x
30 x
150 x

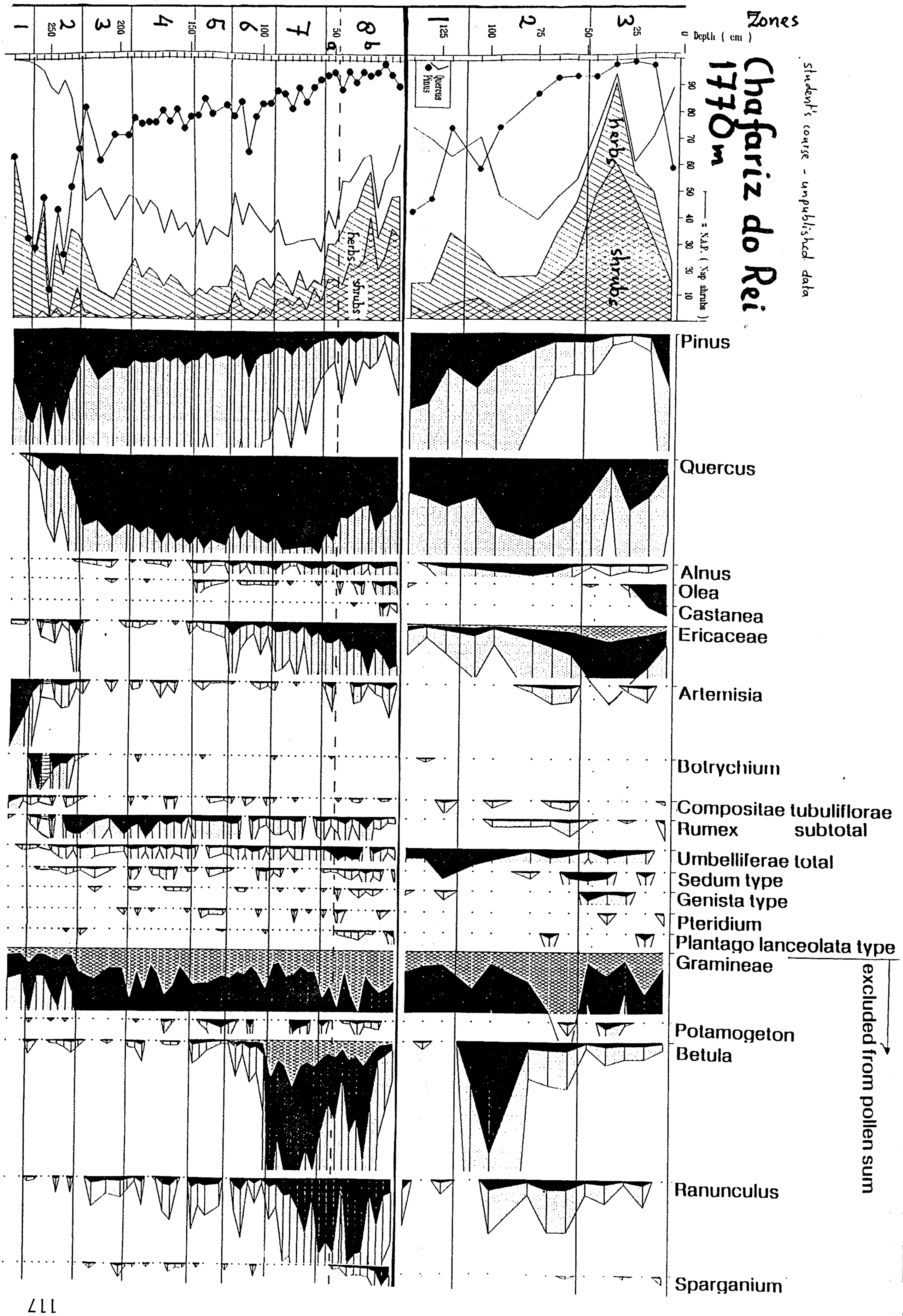


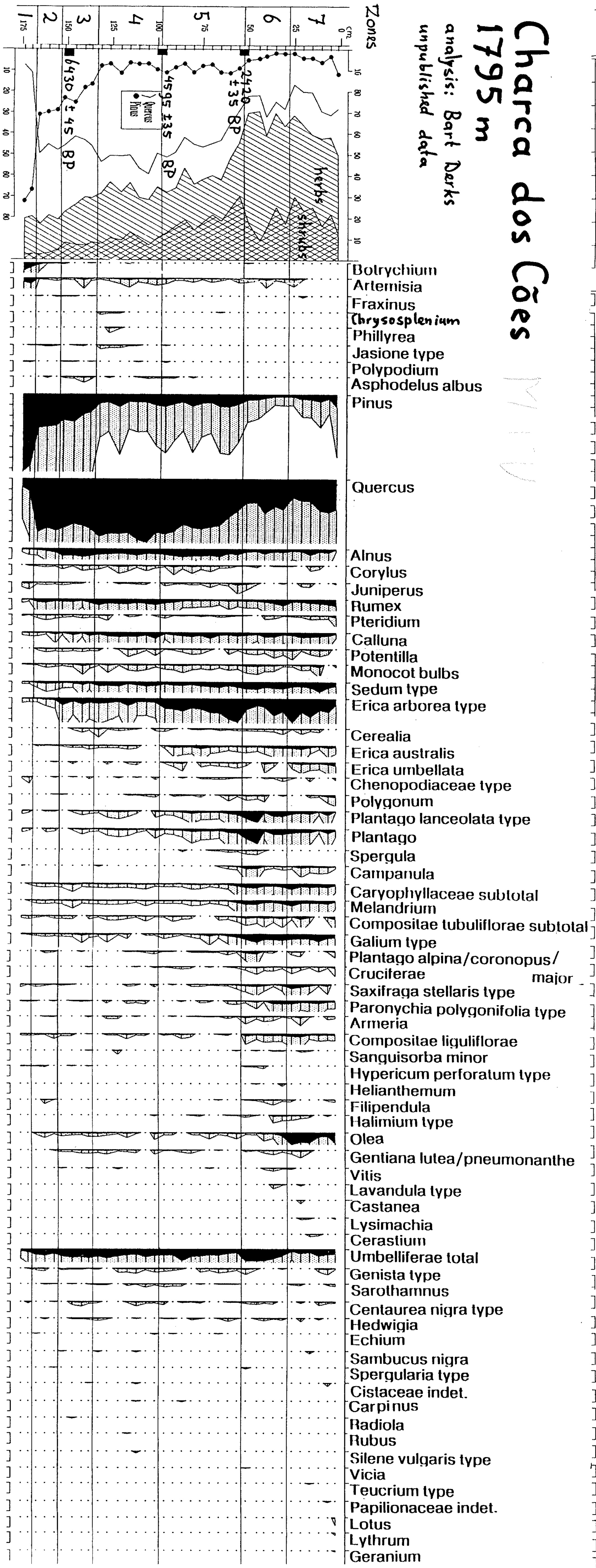
Lagoacho das Favas
1635 m
selected curves
analysis: Frank van Dongen
unpublished data
Zones
6870 ± 100 BP
2725 ± 35 BP
Pinus
Physospermum
Botrychium
Rosaceae indet.
Taxus
Quercus
Saxifraga stellaris type
Frangula
Daucus
Eryngium
Chaerophyllum temulentum
Peucedanum type
Alnus
Corylus
Sarothamnus
Asphodelus albus
Sanguisorba minor
Ulmus
Sorbus
Cirsium type
Ilex
Daphne
Merendera
Calluna
Genista type
Erica arborea type
Erica australis
Pteridium
Erica umbellata
Artemisia
Hedwigia
Plantago lanceolata type
Compositae liguliflorae
Anthemis type
Cerealia
Vitis
Castanea
Olea
Rumex acetosella type
Umbelliferae total
Sedum type
Phillyrea
Fraxinus
Pistacia
Chenopodiaceae type
Plantago major type
Umbelliferae indet.
Jasione type
Aster type
Galium type
Silene foetida type
Potentilla
Echium
Juniperus
Gentiana lutea/pneumonanthe
Narcissus bulbocodium
Armeria
Betula
excluded from pollen sum
Salix
Dryopteris
Sparganium
Gramineae
Cyperaceae
Ranunculus
Potamogeton
Sphagnum
Menyanthes
Nymphaea
Lemna
Myriophyllum alterniflorum
Hepaticeae
1 2 3 4a b 5 6 7 Zones

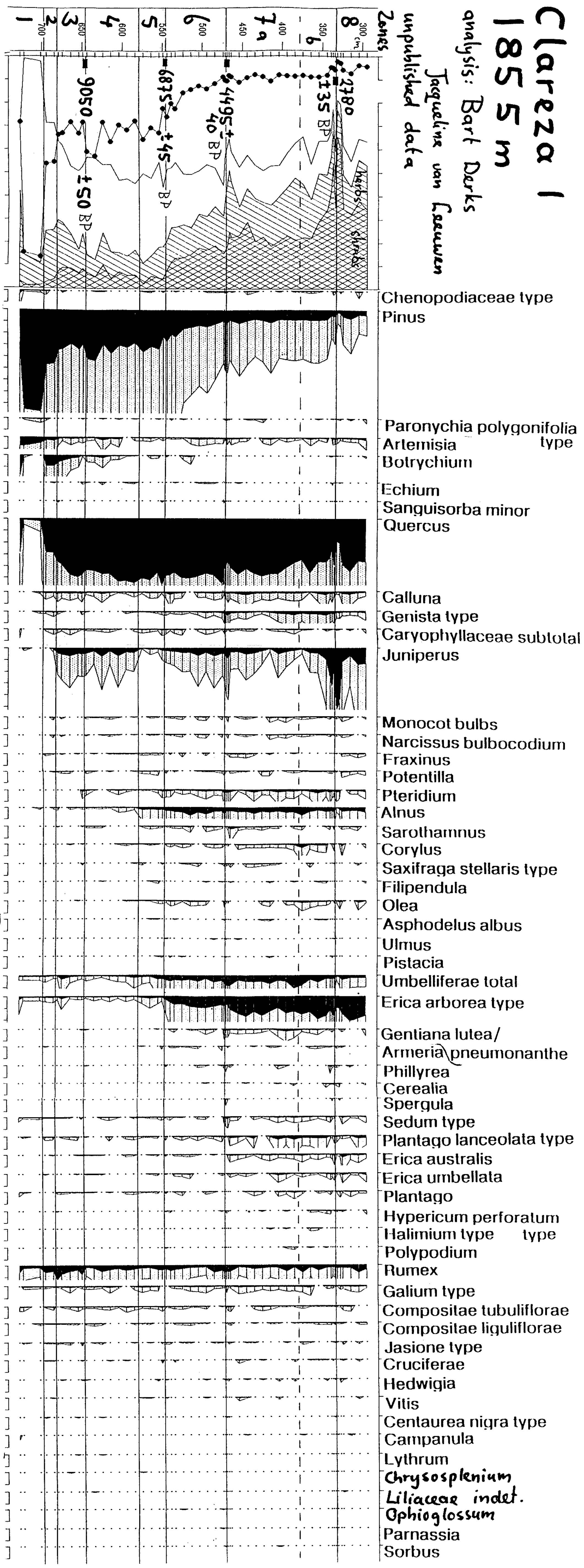

Covão do Boieiro
1725 m
analysis: Hanneke Bos
unpublished data
Zones
cm
9950±60 BP
9600±45 BP
7325±40 BP
5565±35 BP
1600±25 BP
herbs
shrubs
Ephedra
Sanguisorba minor
Lotus
Artemisia
Botrychium
Paronychia polygonifolia type
Plantago alpina type
Plantago coronopus type
Compositae liguliflorae
Chenopodiaceae type
Juniperus
Pinus
Caryophyllaceae subtotal
Campanulaceae
Sedum type
Quercus
Rumex acetosella type
Vitis
Saxifraga stellaris type
Taxus
Olea
Rumex obtusifolius type
Echium
Fraxinus
Centaurea nigra type
Compositae tubuliflorae
Erica arborea type subtotal
Cerealia
Umbelliferae total
Genista type
Asphodelus albus
Alnus
Fritillaria
Corylus
Cruciferae
Gentiana lutea/pneumonanthe
Armeria
Helianthemum
Vicia
Aconitum
Labiatae indet.
Hypericum perforatum type
Halimium type
Plantago major type
Erica australis
Rhinanthus type
Narcissus bulbocodium
Narcissus pseudonarcissus type
Calluna
Plantago lanceolata type
Monocot bulbs
Pteridium
Dipsacaceae
Spergularia type
Erica umbellata
Filipendula
Castanea
Urtica
Papilionaceae indet.
Acer
Polygonum aviculare type
Lavandula type
Geranium
Rhamnus
Ulmus

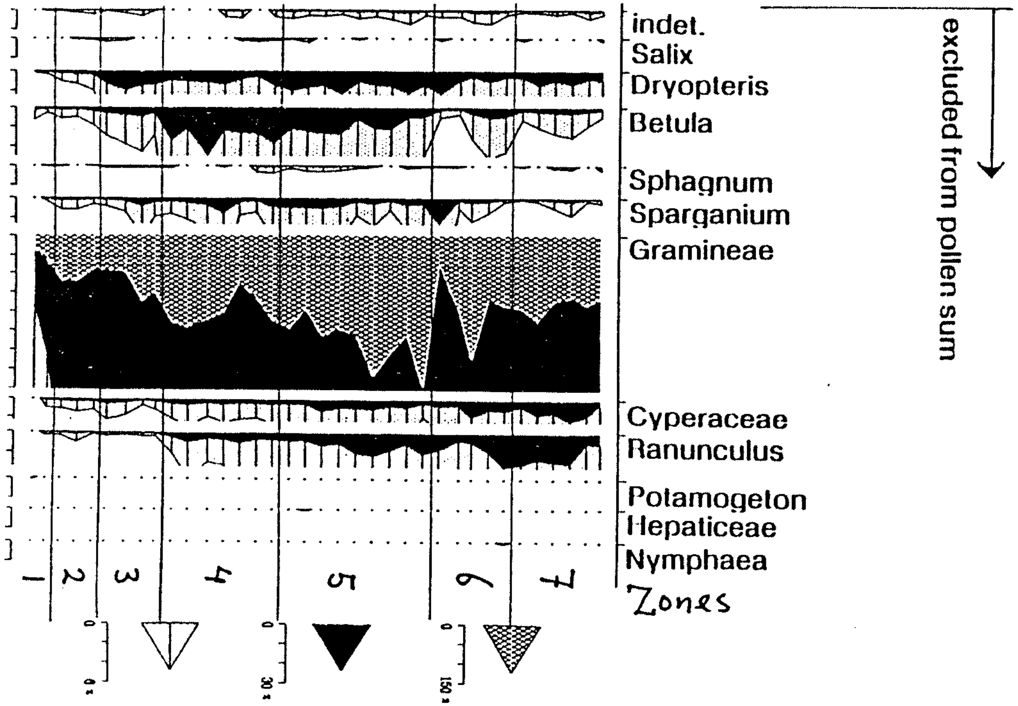


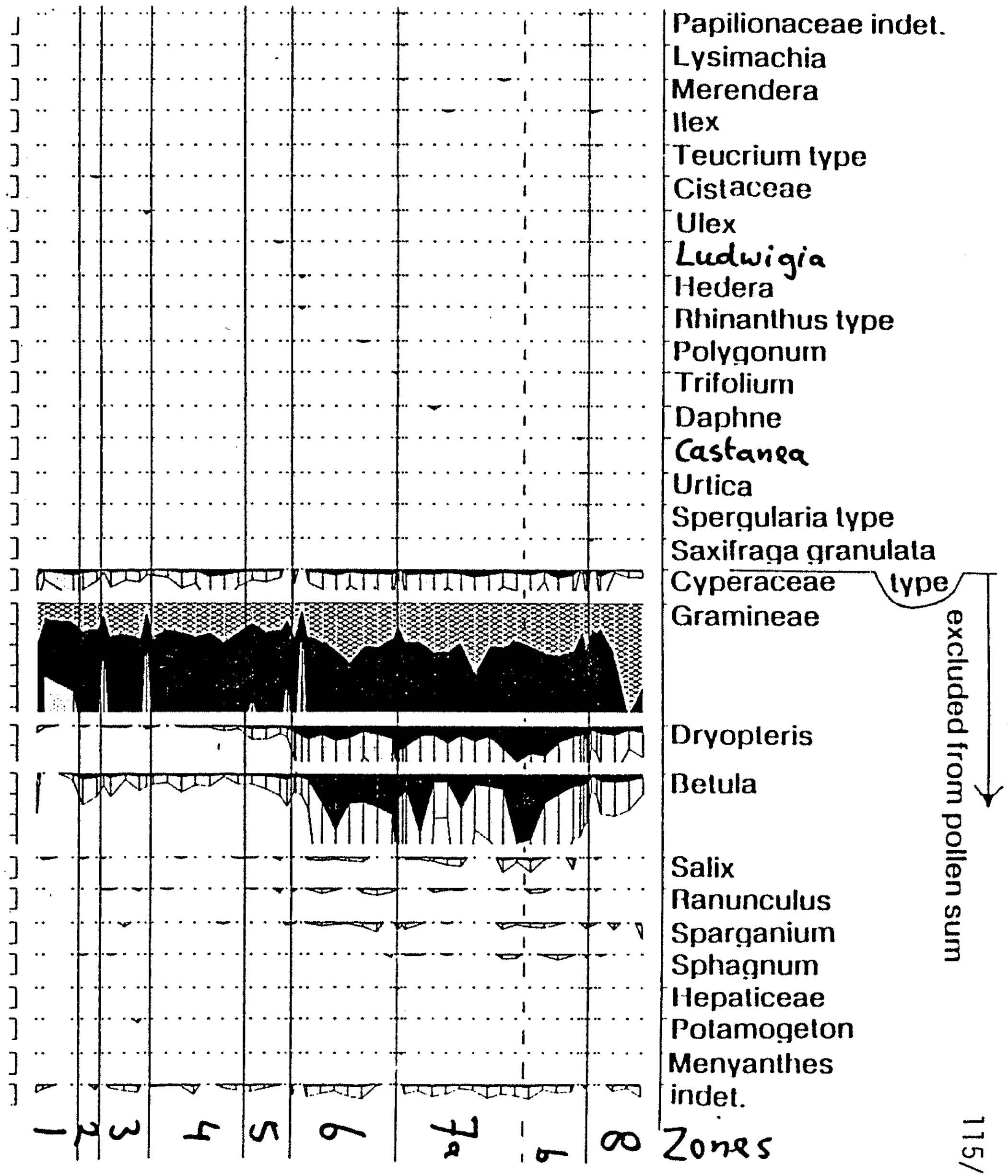
Pistacia
Lysimachia
Hedera
Knautia
Phillyrea
Sorbus
Cistus ladanifer type
Potamogeton
Sparganium
Dryopteris
Salix
Betula
excluded from pollen sum
Isoetes
Cyperaceae
Potentilla
Gramineae
Ranunculus
Galium type
Equisetum
Sphagnum
Chrysosplenium
Hydrocharis
excluded from pollen sum
1
2
3
4
5
6
7
8
9
10
11
ndet.
ype
ype
anulata
type
n

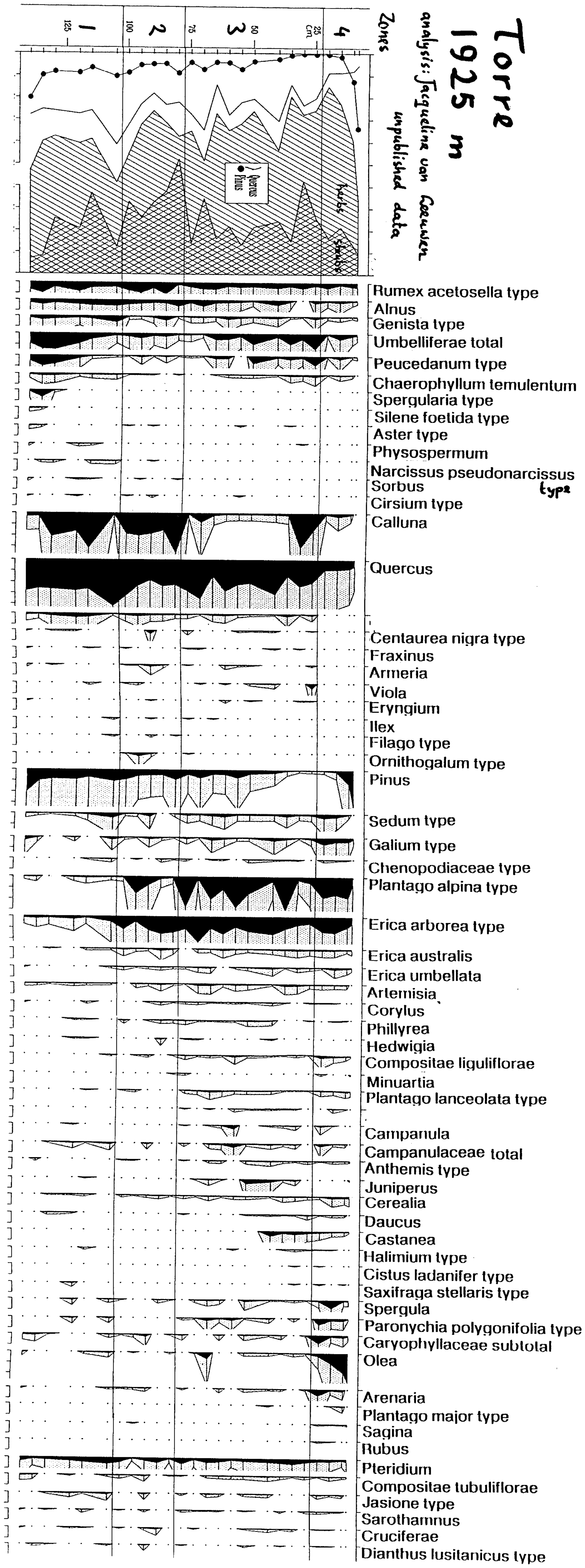

Zones
Depth (cm)
Chafariz do Rei
1770m
student's course - unpublished data
Quercus
Pinus
= N.A.P. (Nap shrubs)
herbs
shrubs
Pinus
Quercus
Alnus
Olea
Castanea
Ericaceae
Artemisia
Botrychium
Compositae tubuliflorae
Rumex subtotal
Umbelliferae total
Sedum type
Genista type
Pteridium
Plantago lanceolata type
Gramineae
Potamogeton
Betula
Ranunculus
Sparganium
excluded from pollen sum


Charca dos Cões
1795 m
analysis: Bart Derks
unpublished data
Zones
1
2
3
4
5
6
7
cm
175
150
125
100
75
50
25
0
6430 ± 45 BP
4595 ± 35 BP
2420 ± 35 BP
Quercus
Pinus
herbs
shrubs
Botrychium
Artemisia
Fraxinus
Chrysosplenium
Phillyrea
Jasione type
Polypodium
Asphodelus albus
Pinus
Quercus
Alnus
Corylus
Juniperus
Rumex
Pteridium
Calluna
Potentilla
Monocot bulbs
Sedum type
Erica arborea type
Cerealia
Erica australis
Erica umbellata
Chenopodiaceae type
Polygonum
Plantago lanceolata type
Plantago
Spergula
Campanula
Caryophyllaceae subtotal
Melandrium
Compositae tubuliflorae subtotal
Galium type
Plantago alpina/coronopus/major
Cruciferae
Saxifraga stellaris type
Paronychia polygonifolia type
Armeria
Compositae liguliflorae
Sanguisorba minor
Hypericum perforatum type
Helianthemum
Filipendula
Halimium type
Olea
Gentiana lutea/pneumonanthe
Vitis
Lavandula type
Castanea
Lysimachia
Cerastium
Umbelliferae total
Genista type
Sarothamnus
Centaurea nigra type
Hedwigia
Echium
Sambucus nigra
Spergularia type
Cistaceae indet.
Carpinus
Radiola
Rubus
Silene vulgaris type
Vicia
Teucrium type
Papilionaceae indet.
Lotus
Lythrum
Geranium

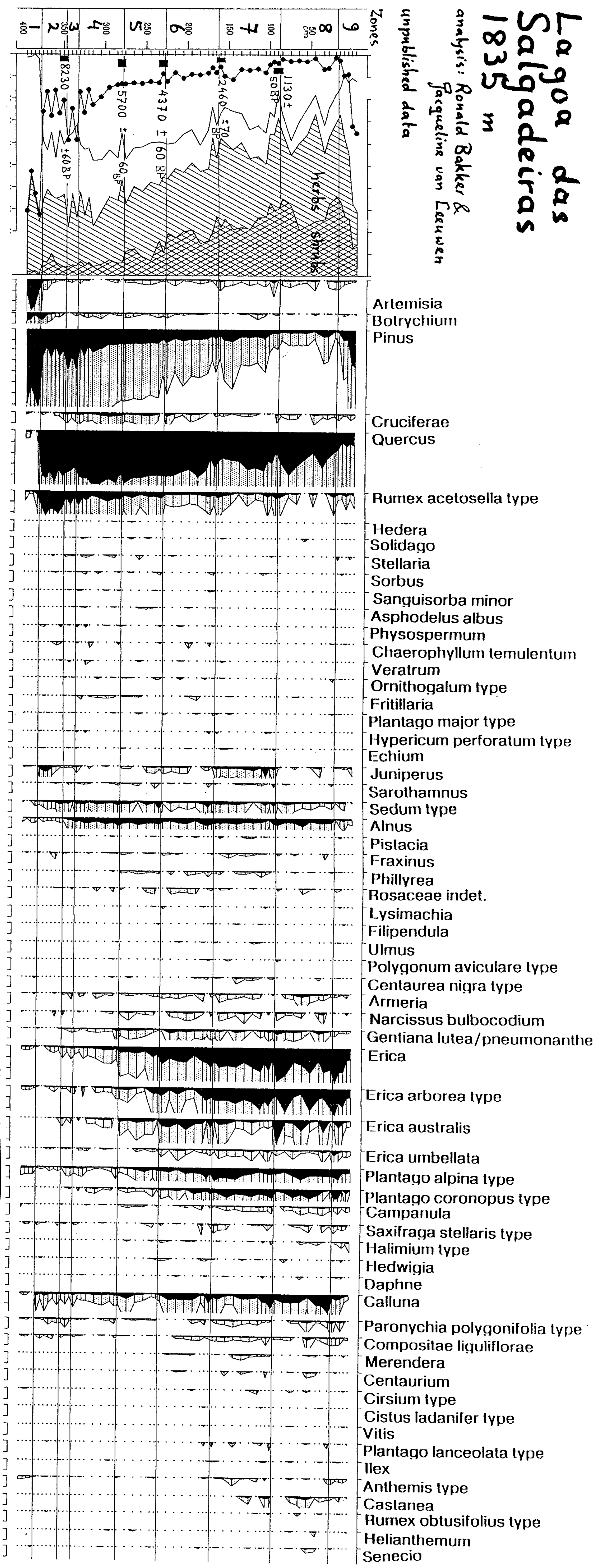

Clareza I
1855 m
analysis: Bart Derks
Jacqueline van Leeuwen
unpublished data
Zones
1
2
3
4
5
6
7a
7b
8
cm
700
650
600
550
500
450
400
350
300
9050 ± 50 BP
6875 ± 45 BP
4495 ± 40 BP
2780 ± 35 BP
herbs
shrubs
Chenopodiaceae type
Pinus
Paronychia polygonifolia type
Artemisia
Botrychium
Echium
Sanguisorba minor
Quercus
Calluna
Genista type
Caryophyllaceae subtotal
Juniperus
Monocot bulbs
Narcissus bulbocodium
Fraxinus
Potentilla
Pteridium
Alnus
Sarothamnus
Corylus
Saxifraga stellaris type
Filipendula
Olea
Asphodelus albus
Ulmus
Pistacia
Umbelliferae total
Erica arborea type
Gentiana lutea/pneumonanthe
Armeria
Phillyrea
Cerealia
Spergula
Sedum type
Plantago lanceolata type
Erica australis
Erica umbellata
Plantago
Hypericum perforatum type
Halimium type
Polypodium
Rumex
Galium type
Compositae tubuliflorae
Compositae liguliflorae
Jasione type
Cruciferae
Hedwigia
Vitis
Centaurea nigra type
Campanula
Lythrum
Chrysosplenium
Liliaceae indet.
Ophioglossum
Parnassia
Sorbus


indet.
Salix
Dryopteris
Betula
Sphagnum
Sparganium
Gramineae
Cyperaceae
Ranunculus
Potamogeton
Hepaticeae
Nymphaea
excluded from pollen sum
1 2 3 4 5 6 7
Zones

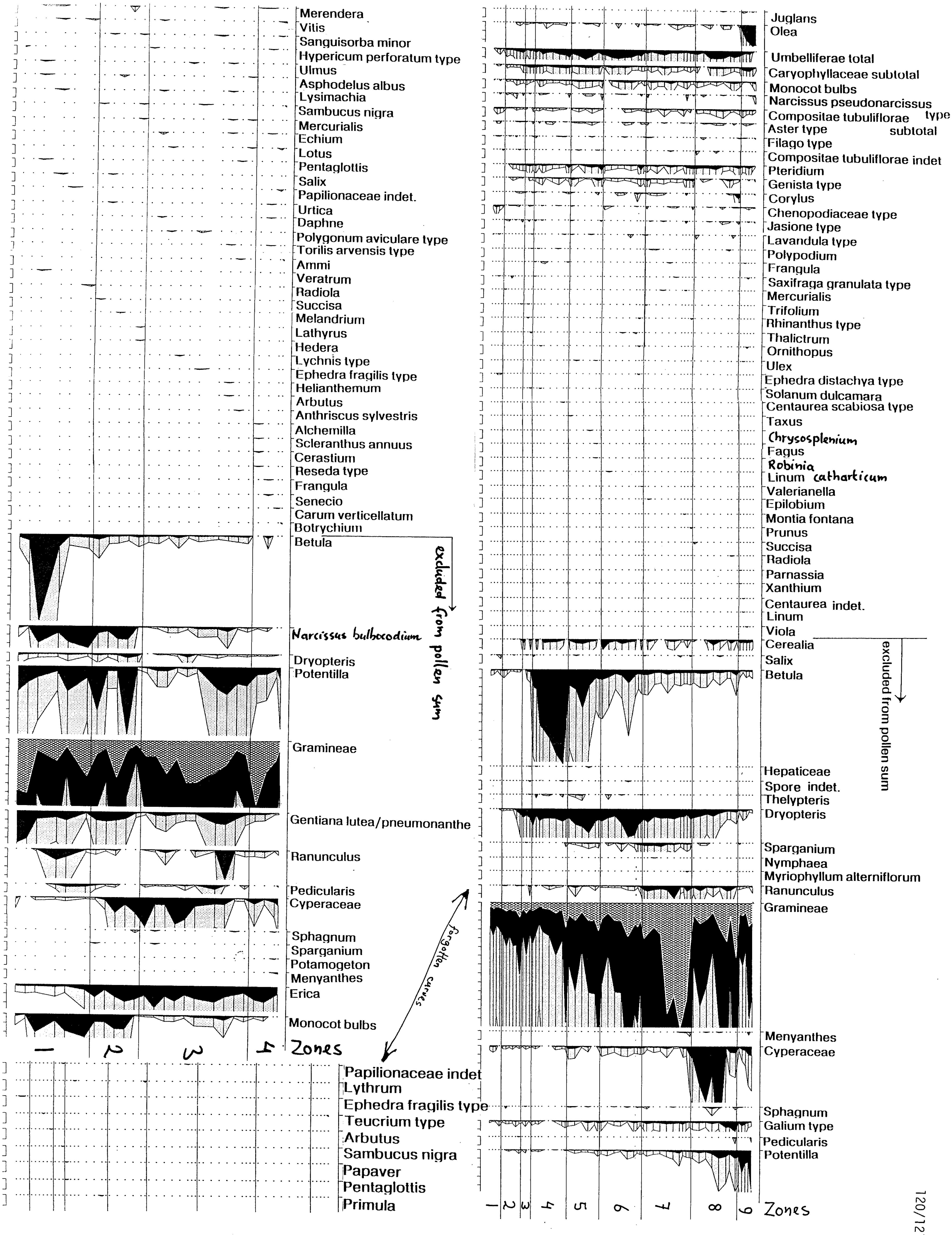

Papilionaceae indet.
Lysimachia
Merendera
Ilex
Teucrium type
Cistaceae
Ulex
Ludwigia
Hedera
Rhinanthus type
Polygonum
Trifolium
Daphne
Castanea
Urtica
Spergularia type
Saxifraga granulata
Cyperaceae type
Gramineae
Dryopteris
Betula
Salix
Ranunculus
Sparganium
Sphagnum
Hepaticeae
Potamogeton
Menyanthes
indet.
excluded from pollen sum
1 2 3 4 5 6 7a b 8
Zones

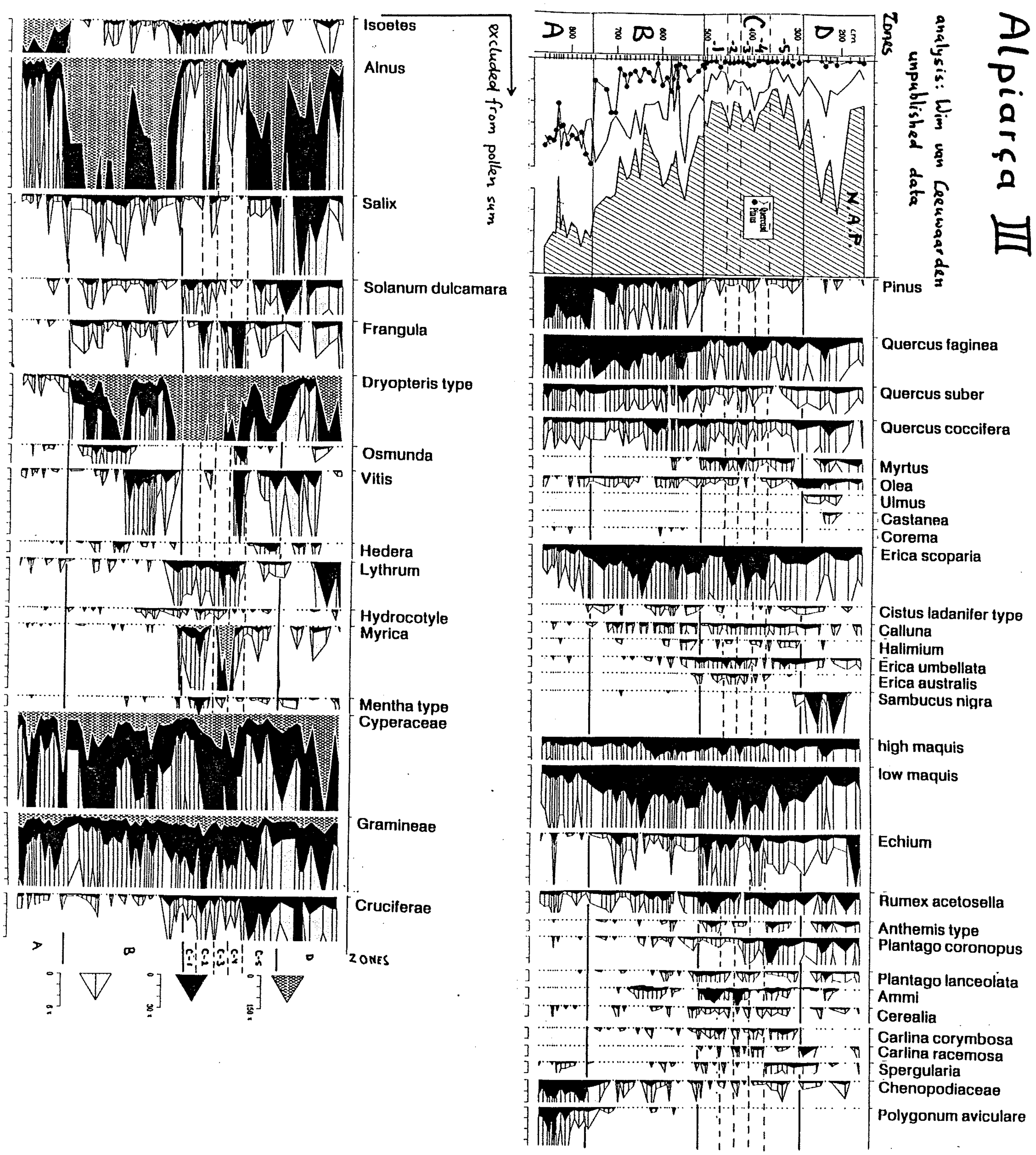


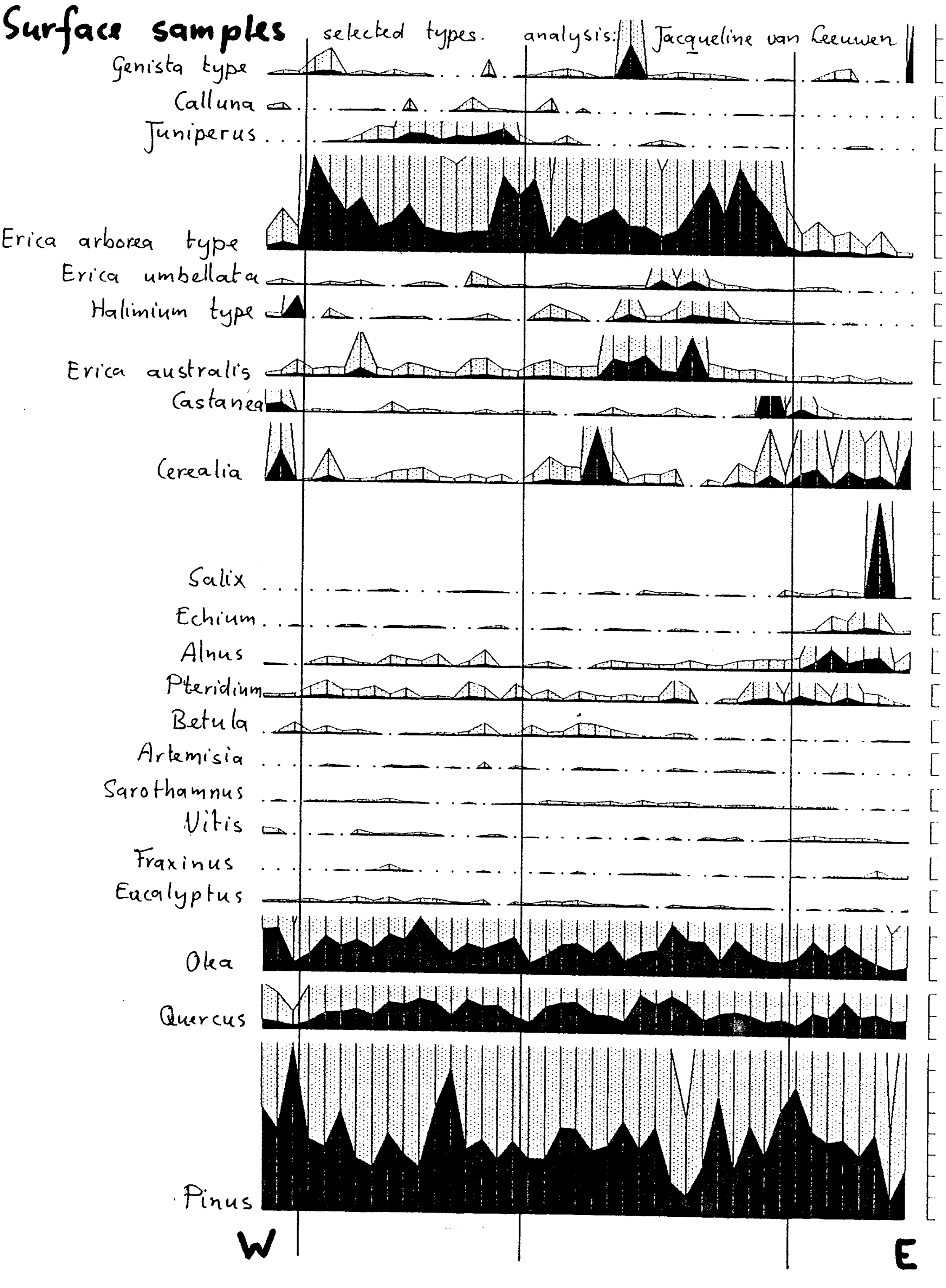
Torre
1925 m
analysis: Jacqueline van Leeuwen
unpublished data
Zones
1
2
3
4
125
100
75
50
25 cm
Quercus
Pinus
herbs
shrubs
Rumex acetosella type
Alnus
Genista type
Umbelliferae total
Peucedanum type
Chaerophyllum temulentum
Spergularia type
Silene foetida type
Aster type
Physospermum
Narcissus pseudonarcissus type
Sorbus
Cirsium type
Calluna
Quercus
Centaurea nigra type
Fraxinus
Armeria
Viola
Eryngium
Ilex
Filago type
Ornithogalum type
Pinus
Sedum type
Galium type
Chenopodiaceae type
Plantago alpina type
Erica arborea type
Erica australis
Erica umbellata
Artemisia
Corylus
Phillyrea
Hedwigia
Compositae liguliflorae
Minuartia
Plantago lanceolata type
Campanula
Campanulaceae total
Anthemis type
Juniperus
Cerealia
Daucus
Castanea
Halimium type
Cistus ladanifer type
Saxifraga stellaris type
Spergula
Paronychia polygonifolia type
Caryophyllaceae subtotal
Olea
Arenaria
Plantago major type
Sagina
Rubus
Pteridium
Compositae tubuliflorae
Jasione type
Sarothamnus
Cruciferae
Dianthus lusitanicus type



Lagoa das Salgadeiras
1835 m
analysis: Ronald Bakker & Jacqueline van Leeuwen
unpublished data
Zones
1
2
3
4
5
6
7
8
9
400
350
300
250
200
150
100
50 cm
8230 ±60 BP
5700 ± 60 BP
4370 ± 60 BP
2460 ± 70 BP
1130 ± 50 BP
herbs
shrubs
Artemisia
Botrychium
Pinus
Cruciferae
Quercus
Rumex acetosella type
Hedera
Solidago
Stellaria
Sorbus
Sanguisorba minor
Asphodelus albus
Physospermum
Chaerophyllum temulentum
Veratrum
Ornithogalum type
Fritillaria
Plantago major type
Hypericum perforatum type
Echium
Juniperus
Sarothamnus
Sedum type
Alnus
Pistacia
Fraxinus
Phillyrea
Rosaceae indet.
Lysimachia
Filipendula
Ulmus
Polygonum aviculare type
Centaurea nigra type
Armeria
Narcissus bulbocodium
Gentiana lutea/pneumonanthe
Erica
Erica arborea type
Erica australis
Erica umbellata
Plantago alpina type
Plantago coronopus type
Campanula
Saxifraga stellaris type
Halimium type
Hedwigia
Daphne
Calluna
Paronychia polygonifolia type
Compositae liguliflorae
Merendera
Centaurium
Cirsium type
Cistus ladanifer type
Vitis
Plantago lanceolata type
Ilex
Anthemis type
Castanea
Rumex obtusifolius type
Helianthemum
Senecio


Merendera
Vitis
Sanguisorba minor
Hypericum perforatum type
Ulmus
Asphodelus albus
Lysimachia
Sambucus nigra
Mercurialis
Echium
Lotus
Pentaglottis
Salix
Papilionaceae indet.
Urtica
Daphne
Polygonum aviculare type
Torilis arvensis type
Ammi
Veratrum
Radiola
Succisa
Melandrium
Lathyrus
Hedera
Lychnis type
Ephedra fragilis type
Helianthemum
Arbutus
Anthriscus sylvestris
Alchemilla
Scleranthus annuus
Cerastium
Reseda type
Frangula
Senecio
Carum verticellatum
Botrychium
Betula
excluded from pollen sum
Narcissus bulbocodium
Dryopteris
Potentilla
Gramineae
Gentiana lutea/pneumonanthe
Ranunculus
Pedicularis
Cyperaceae
Sphagnum
Sparganium
Potamogeton
Menyanthes
Erica
Monocot bulbs
1 2 3 4 Zones
forgotten curves
Papilionaceae indet
Lythrum
Ephedra fragilis type
Teucrium type
Arbutus
Sambucus nigra
Papaver
Pentaglottis
Primula
Juglans
Olea
Umbelliferae total
Caryophyllaceae subtotal
Monocot bulbs
Narcissus pseudonarcissus
Compositae tubuliflorae type
Aster type subtotal
Filago type
Compositae tubuliflorae indet
Pteridium
Genista type
Corylus
Chenopodiaceae type
Jasione type
Lavandula type
Polypodium
Frangula
Saxifraga granulata type
Mercurialis
Trifolium
Rhinanthus type
Thalictrum
Ornithopus
Ulex
Ephedra distachya type
Solanum dulcamara
Centaurea scabiosa type
Taxus
Chrysosplenium
Fagus
Robinia
Linum cathartícum
Valerianella
Epilobium
Montia fontana
Prunus
Succisa
Radiola
Parnassia
Xanthium
Centaurea indet.
Linum
Viola
Cerealia
Salix
Betula
excluded from pollen sum
Hepaticeae
Spore indet.
Thelypteris
Dryopteris
Sparganium
Nymphaea
Myriophyllum alterniflorum
Ranunculus
Gramineae
Menyanthes
Cyperaceae
Sphagnum
Galium type
Pedicularis
Potentilla
1 2 3 4 5 6 7 8 9 Zones


Alpiarça III
analysis: Wim van Leeuwaarden
unpublished data
Zones
A
B
C
-1
-2
-3
-4
-5
D
N.A.P.
Quercus
Pinus
excluded from pollen sum
Isoetes
Alnus
Salix
Solanum dulcamara
Frangula
Dryopteris type
Osmunda
Vitis
Hedera
Lythrum
Hydrocotyle
Myrica
Mentha type
Cyperaceae
Gramineae
Cruciferae
ZONES
Pinus
Quercus faginea
Quercus suber
Quercus coccifera
Myrtus
Olea
Ulmus
Castanea
Corema
Erica scoparia
Cistus ladanifer type
Calluna
Halimium
Erica umbellata
Erica australis
Sambucus nigra
high maquis
low maquis
Echium
Rumex acetosella
Anthemis type
Plantago coronopus
Plantago lanceolata
Ammi
Cerealia
Carlina corymbosa
Carlina racemosa
Spergularia
Chenopodiaceae
Polygonum aviculare


Surface samples
selected types.
analysis: Jacqueline van Leeuwen
Genista type
Calluna
Juniperus
Erica arborea type
Erica umbellata
Halimium type
Erica australis
Castanea
Cerealia
Salix
Echium
Alnus
Pteridium
Betula
Artemisia
Sarothamnus
Vitis
Fraxinus
Eucalyptus
Olea
Quercus
Pinus
W
E