Type regions F-zg and F-r, the northen slope of the Pyrenees

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TYPE REGIONS F-zg AND F-r, THE NORTHERN SLOPE OF THE PYRENEES (G. Jalut, S. Aubert, D. Galop, M. Fontugne and J.M. Belet)

Running from the Atlantic Ocean to the Mediterranean Sea, the Pyrenees form the westernmost mountain chain of general E–W orientation in the south of western Europe. Such an intermediate geographical position between the Atlantic and Mediterranean climatic zones gives rise to large phytogeographical differences between southern and northern slopes, as well as a climatic gradient along the French slope. For this reason, two main regions can be distinguished: an Atlantic zone (F-r), including the western part and the Ariège region, which is climatically and botanically an intermediate zone; and the eastern part, with a Mediterranean climate. The latter belongs to a heterogenous type region F-zg, and only the Pyrenean zone is considered here.

Because of its geologic and geomorphologic structure, the Pyrenean chain shows in each of these zones a great diversity of local climatic characteristics, especially in the eastern part, where the axis is divided into three sections with different glacial histories during the last ice age. In the Atlantic area glaciers 50–70 km long spread over the piedmont, whereas in the Mediterranean Pyrenees the glacial tongues did not exceed 20 km (Hérail *et al.* 1987), being confined to the mountains. At middle and low elevations, the complex topography and the proximity of the Mediterranean provided numerous plant refuges (Jalut 1974, Jalut *et al.* 1975, Vernet 1980).

Along the northern slope of the Pyrenees five sites have been selected. Three are situated in the Atlantic area (F-r) and two in the eastern Mediterranean part of the chain (F-zg) (Fig. 17.27).

TYPE REGION F-zg, EASTERN PYRENEES, MEDITERRANEAN PYRENEES

Altitude: 0–2921 m.

Climate: Great diversity: Mediterranean type at low elevation. To the north, at middle elevation (1300–1500 m), attenuated oceanic type with high precipitation in spring, autumn, and winter. In the high valleys of the Aude and Têt (1600–1700 m), semi-continental climate (Fig. 17.27).

Geology: In the axial zone granite, crystalline schist, and gneiss, and also Devonian limestone and Silurian schist. To the north, Urgo-Aptian limestone of the Mesozoic sedimentary mantle.

Topography: Very complex. The area is divided by four main valleys: Aude, Agly, Têt, and Tech. To the north the Aude River and its tributaries cut the Urgo-Aptian limestone and are deeply enclosed. The other valleys open wide to the Mediterranean and are generally oriented E–W or NE–SW. In this region at the limit between the Atlantic and Mediterranean zones the short distance between the high summits and the Mediterranean Sea, as well as the complex topography, are the most important characteristics determining the regional plant distribution.

Population: The population is concentrated in the villages and small towns of the cultivated zones at low altitude, whereas the mountain villages have a low population.

Vegetation: Because of the complex topography, climatic diversity, and human influence, various types can be observed from Mediterranean to alpine zones. At low and middle elevations the deciduous tree vegetation consists mainly of *Quercus* and *Fagus sylvatica*, whereas *Betula* and *Corylus* are more restricted. *Abies alba* and *Pinus* are widely developed in the mountain and subalpine zones. In the Mediterranean area evergreen oaks prevail: *Quercus ilex*, *Q. coccifera*, *Q. suber*.

Soils: From alpine rankers to rendzinas and Mediterranean red soils.

Land use: In the Mediterranean area, the plains

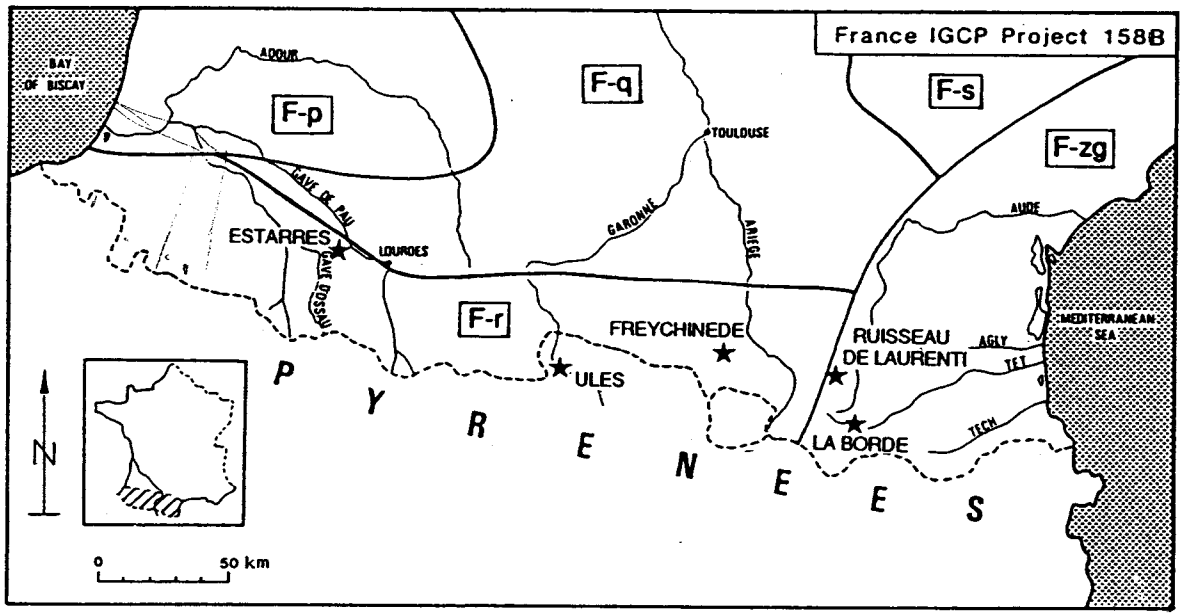


Fig. 17.27 Type regions (F-r and F-zg) and mentioned reference sites in the northern Pyrenees

zones are devoted to vineyards, orchards, and market gardens. In the mountains, forest or pasture.

Reference site 24. Peat bog of La Borde
(Jalut 1974, Reille 1990a and b; Jalut *et al.* 1992; Reille & Lowe 1993)

The site is situated in the high valley of Têt open wide to the Mediterranean. Latitude 42°32′N, Longitude 2°05′E. Elevation: 1660 m. Age range: 14000–5000 BP. 14 local pollen-assemblage zones (paz). (Fig. 17.28)

	Age	Local paz
LB 1	14000–13500 BP	*Artemisia*–Gramineae–*Pinus*–*Juniperus*
LB 2	13500–13000 BP	*Juniperus*–Gramineae–*Betula*–*Artemisia*
LB 3	13000–12000 BP	Gramineae–*Pinus*–*Juniperus*–*Betula*–*Artemisia*
LB 4	12000–11500 BP	*Pinus*–Gramineae–*Betula*–*Juniperus*–*Artemisia*
LB 5	11500–11000 BP	*Pinus*–Gramineae–*Betula*–*Artemisia*
LB 6	11000–10650 BP	*Pinus*–Gramineae–*Artemisia*
LB 7	10650–10000 BP	*Pinus*–Gramineae–*Artemisia*–*Juniperus*
LB 8	10000–9650 BP	*Pinus*–Gramineae–*Juniperus*–*Artemisia*
LB 9	9650–9400 BP	*Pinus*–*Betula*–Gramineae
LB 10	9400–9000 BP	*Pinus*–*Betula*–Gramineae–*Quercus*–*Corylus*–*Ulmus*
LB 11	9000–8650 BP	*Pinus*–*Betula*–Gramineae–*Quercus*–*Corylus*–*Ulmus*–*Populus*
LB 12	8650–7800 BP	*Pinus*–*Betula*–*Quercus*–*Corylus*–*Abies*
LB 13	7800–6000 BP	*Pinus*–*Betula*–*Quercus*–*Abies*–*Corylus*
LB 14	6000–5000 BP	*Pinus*–*Abies*–*Betula*–*Quercus*–*Tilia*–*Fagus*

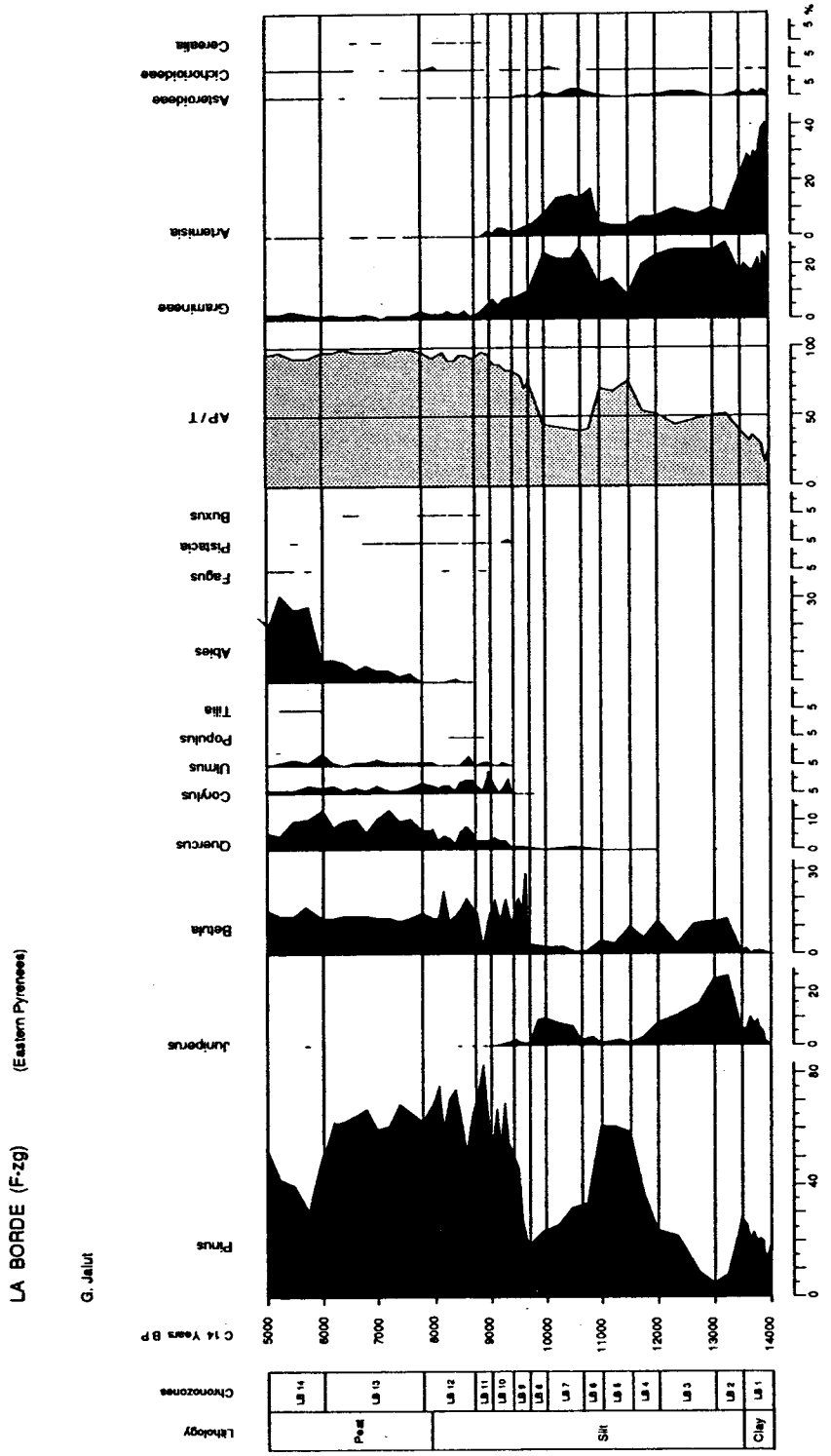


Fig. 17.28 Late-glacial and Holocene pollen diagram from the peat bog of La Borde. Only selected pollen types are shown

General remarks on the pollen diagram

- Strong increase of *Juniperus* near 14000 BP (level 699.5–700: 13630 ± 230 Gif TAN, ^{14}C AMS date on terrestrial macroremains (*Pohlia annotina* (Hedw.) Lindb.)
- Synchronous increase in percentages of *Betula* and *Juniperus* near 13500 BP and importance of *Juniperus* between 13500 and 12000 BP.
- From 12000 BP regular presence of *Quercus*.
- Low values of *Quercus* up to about 9400 BP, then increase in *Quercus* and *Corylus* values.
- *Alnus* and *Fraxinus* only represented by isolated grains.
- First presence of *Populus* dated 8700 ± 140.
- From 8700 to 8600 BP regular presence of *Pistacia*, Cerealia, *Quercus* type *ilex*, then *Buxus*, transported from the Mediterranean area.
- From 8650 BP presence of *Abies*. Then continuous curve from 8270 BP.
- *Tilia* poorly represented.
- *Fagus* present between 6010 and 5240 BP.

Reference site 23. Peat bog of Ruisseau de Laurenti (Jalut 1974, Jalut & Vernet 1989, Reille 1990b, Jalut *et al.* 1992, Reille & Lowe 1993)

Site situated in the high valley of Aude, in northern exposure, at the limit between the Atlantic and Mediterranean climatic zones. Latitude 42°40′30″ N, Longitude 2°1′46″E. Elevation: 1860 m. Age range: 14000–0 BP. 14 local pollen assemblage zones (paz). (Fig. 17.29)

	Age	Local paz
RL 1	14000–13000 BP	*Artemisia–Pinus–* Gramineae
RL 2	13000–12000 BP	*Pinus–Artemisia–* Gramineae–*Betula*
RL 3	12000–11000 BP	*Pinus–Betula*
RL 4	11000–10000 BP	*Pinus–Artemisia–* Gramineae–*Betula–Quercus*
RL 5	10000–9650 BP	*Pinus–Betula–Artemisia–* Gramineae
RL 6	9650–9400 BP	*Pinus–Betula–Quercus*
RL 7	9400–9200 BP	*Pinus–Betula–Quercus–Corylus*
RL 8	9200–8500 BP	*Pinus–Corylus–Betula–Quercus–Ulmus*
RL 9	8500–6200 BP	*Pinus–Corylus–Quercus–Betula–Ulmus–Abies*
RL 10	6200–5000 BP	*Pinus–Betula–Corylus–Abies–Quercus–Ulmus–Alnus*
RL 11	5000–4200 BP	*Pinus–Abies–Betula– Corylus–Quercus–Fagus*
RL 12	4200–3000 BP	*Pinus–Abies–*Gramineae–*Alnus–Fagus–* Cerealia
RL 13	3000–2000 BP	*Pinus–*Gramineae–*Abies–Fagus*
RL 14	2000–0 BP	*Pinus–*Gramineae–*Abies– Fagus–* Cerealia

General remarks on the pollen diagram

- *Pinus* is always well represented.
- During the Late-glacial *Betula* had low values and increased only at the beginning of the Post-glacial.
- Local lack of dates for the Late-glacial phases. Limits are proposed by comparison with other sites.
- *Quercus* then *Corylus* spread early, at the beginning of the Post-glacial, but their maxima occurred near 8500–8000 BP.
- The continuous curve of *Abies* begins about 8300–8200 BP. This agrees with the results obtained in the high valley of Têt (La Borde: about 8580±150, Reille 1990a; 8270 ± 130, Jalut *et al.* 1992). But it is late in comparison with the valley of Nohède (basin of River Têt) in the same type region, where *Abies* is regularly present from about 9500 BP (Jalut 1974) and 9150 BP (Reille 1990b).
- The continuous curve of *Fagus* begins near 5000 BP, but the maximum extent of this species

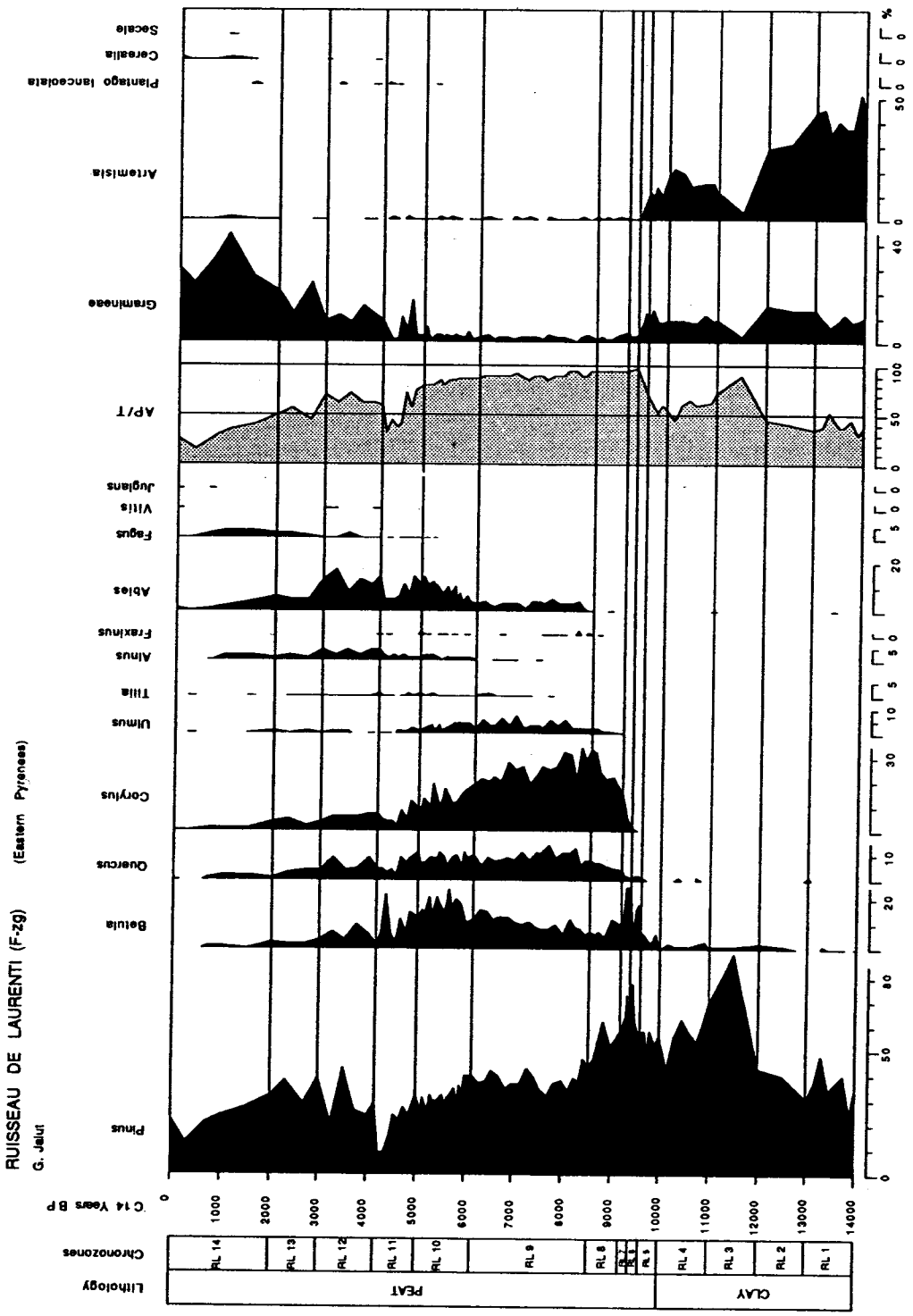


Fig. 17.29 Late-glacial and Holocene pollen diagram from the peat bog of Ruisseau de Laurenti. Only selected pollen types are shown

occurred near 4000 BP and was contemporaneous with the development of human influence.
- Locally the first anthropogenic indicators are found approximately 5000 BP. About 5 km to the northwest of the site, other indicators are observed between 6100 and 4800 BP in peat levels (peat bog of Ruisseau du Fournas: Jalut 1974, Jalut & Vernet 1989) while at the same time sheep and goats were being bred 10 km to the north (Geddes 1980). Northward (peat bog of Pinet) contemporaneous clearances are also recorded (Jalut & Vernet 1989).
- Not dated here, the presence of *Juglans* is recorded at 1100±70 in the same area (Pailhère, Galop unpublished), while in Cerdagne, not far from La Borde, its first presence is dated 760±50 (Pla de l'Orri, Galop unpublished).

Comparison of the two pollen diagrams of type region F-zg

This shows a good representation of the Late-glacial period during which *Quercus* is regularly observed, particularly during the Younger Dryas.
- The *Juniperus* phase is not recorded in the sequences of Ruisseau de Laurenti analysed by Jalut (1974) and Reille (1990b), but it is found very near, in the same high basin, at La Restanque (Reille & Andrieu 1993). Its beginning is contemporaneous with a strong decline of *Artemisia*.
- The continuous curves of *Abies* begin at the same time (La Borde, slightly before 8300±190, Jalut 1971, 1974, 8270±130, Jalut *et al.* 1992; Ruisseau de Laurenti, 8230±180, Jalut 1974; 8250±190, Reille 1990b). Similarly, the first pollen of *Tilia* is found between 7300 and 7000 BP (Jalut 1974, Jalut *et al.* 1992, Reille 1990b).
- *Fagus* is found between 6000 and 5000 BP (Jalut, 1974, Jalut & Vernet 1989, Jalut *et al.* 1992).

TYPE REGION F-r, ARIEGE

Altitude: 250–3115 m.

Climate: Northwest Atlantic disturbances with maximum rainfall in winter and spring. The complex topography induces highly contrasted local climatic conditions.

Geology: In the mountain zone, two main formations: the crystalline block of the axial chain with granite, gneiss, and micaschist, and the Urgo-Aptian limestone of the Mesozoic sedimentary mantle.

Topography: Very complex geological structure. Many deep valleys of various orientations.

Population: Very low in the mountains, where many small villages or hamlets are partially abandoned. Remaining population concentrated in small towns.

Vegetation: Great diversity, depending on geology, complex topography, altitude, and climatic situation. Up to 1400–1500 m, *Quercus* and *Ulmus* are well developed, with local *Tilia* stands and abundant *Fraxinus*. *Fagus* is extensive due to human influence. Stands of *Abies* are only present in certain valleys. On many slopes *Fagus* has been replaced by heathland or pasture. In several parts of the subalpine zone, the *Pinus* forest, especially with *Pinus uncinata*, has been completely destroyed. The calcareous rocks are commonly covered with a vegetation of Mediterranean and sub-Mediterranean type in which is observed the large stand of *Juniperus thurifera* of Quié de Lujat (Guerby 1993).

Soils: Alpine soils, forest brown soils, some rendzinas.

Land use: Large uncultivated areas, forest and pasture.

Reference site 21. Peat bog of Freychinède
(Jalut *et al.* 1982, Reille 1993a and b)

Latitude 42°48'N, Longitude 1°26'11"E. Elevation 1350 m. Age range 15000–0 BP. 14 local pollen assemblage zones (paz). (Fig 17.30)

	Age	Local paz
Fr 1	14500–14000 BP	*Artemisia*–Gramineae–*Pinus*
Fr 2	14000–13200 BP	Gramineae–*Artemisia*–*Pinus*–*Juniperus*
Fr 3	13200–12000 BP	Gramineae–*Betula*–*Artemisia*–*Pinus*–*Juniperus*
Fr 4	12000–11600 BP	Gramineae–*Pinus*–*Artemisia*–*Betula*

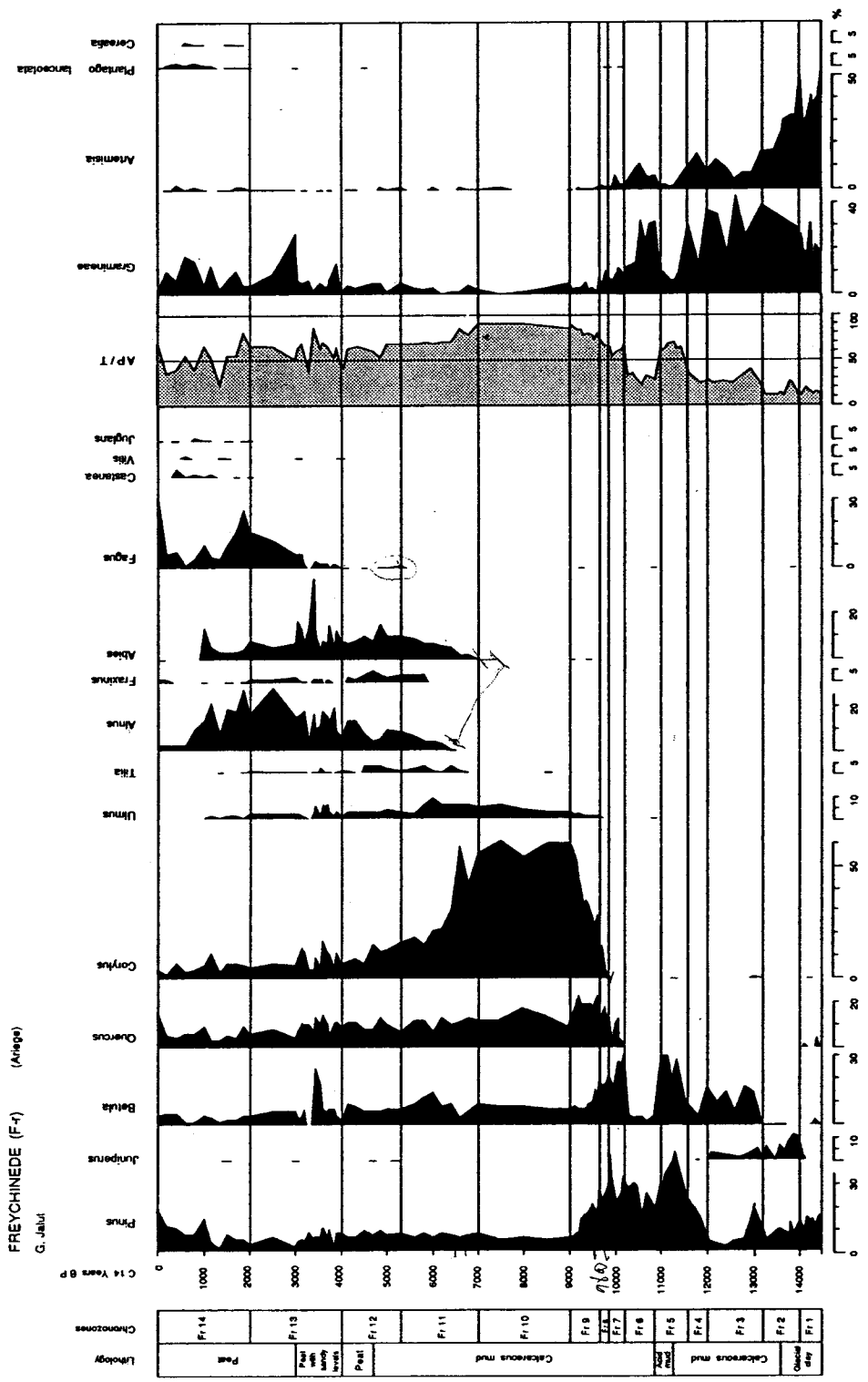


Fig. 17.30 Late-glacial and Holocene pollen diagram from the peat bog of Freychinede. Only selected pollen types are shown

	Age	Local paz
Fr 5	11600–11000 BP	*Pinus–Betula–* Gramineae–*Artemisia*
Fr 6	11000–10200 BP	*Pinus*–Gramineae–*Artemisia–Betula*
Fr 7	10200–9850 BP	*Pinus–Betula–Quercus*–Gramineae–*Artemisia*
Fr 8	9850–9700 BP	*Pinus–Betula–Quercus–Corylus*–Gramineae
Fr 9	9700–9000 BP	*Corylus–Quercus–Pinus–Betula–Ulmus*
Fr 10	9000–7000 BP	*Corylus–Quercus–Betula–Pinus–Ulmus*
Fr 11	7000–5300 BP	*Corylus–Quercus–Abies–Alnus–Tilia*
Fr 12	5300–4000 BP	*Abies–Alnus–Fraxinus–Fagus*
Fr 13	4000–2000 BP	*Alnus–Fagus–Abies*
Fr 14	2000–0 BP	*Alnus–Fagus–Abies–Castanea–Juglans–* Cerealia

General remarks on the pollen diagram

- From 14500 to 12000 BP the *Pinus* values are low.
- From 14500 to 14000 BP *Artemisia* pollen is more abundant than Gramineae, then Gramineae dominates.
- Near 14000 BP a *Juniperus* phase begins while the *Artemisia* values decrease. *Juniperus* is well represented up to about 12000 BP.
- From 13200 to 12000 BP *Betula* is more abundant than *Pinus*, but the landscape stays poorly forested. Between 12000 and 11000 BP the presence of stomata of *Pinus* demonstrates the local presence of this tree at the altitude of the lake (Reille & Andrieu 1993).
- The continuous curve of *Quercus* begins before 10000 BP. *Quercus* followed by *Corylus* develop and reach their maximum between 9500 and 9000 BP and 9000 and 7000 BP, respectively.
- The date of the *Abies* expansion differs according to the sedimentary sequences studied (7100–7000 BP, Jalut *et al.* 1982; near 8500 BP, Reille 1993a). In the site of l'Estagnon near Freychinède the beginning of the continuous curve of *Abies* is dated 6690±70 (Reille 1993 a).
- *Fagus* is present from 5300 to 5200 BP, but its strong development occurred around 4000 BP. At the same time the first anthropogenic indicators are noticed.
- From 2000 BP onwards the local human impact is very strong. One of its most important consequences is the momentary local extinction of *Abies* and its substitution for *Fagus*. The beginning of the *Juglans* curve is dated at 2000 BP, and at Argentières near Freychinède at 1850±50 (Galop unpublished).

TYPE REGION F-r, CENTRAL PYRENEES

Altitude: 400–3404 m.

Climate: Northwest Atlantic impact with maximum precipitation in spring and winter. In the high valley of Garonne (Val of Aran, basin of Oo), slight continental tendency due to the sheltered situation of the valleys. In these cases, precipitation is less important in winter but increases in summer with more contrasted temperature.

Geology:
Three zones:
- The North Pyrenean zone is strongly folded, with sheets of Palaeozoic basement, with a Mesozoic cover (Triassic up to Cretaceous).
- A complex fault zone (north Pyrenean vertical fault). Zone of Mesozoic marble and schist.
- The high primary range with Hercynian basement (sedimentary and metamorphic formations) injected by intrusive granite (Aneto, 3404 m). All the geological formations concerned correspond to the Pyrenean mountain complex, at the boundary between the European plate (overlapping) and Iberian plate (overlapped).

Vegetation: Great diversity depending on geology, topography, altitude, and climatic situation. At low elevation on limestone, a *Quercus pubescens* forest is well developed with some stands of *Quercus ilex* and a stand of *Juniperus thurifera* (Marignac). Above, *Fagus* is extensive but *Abies* expands progressively.

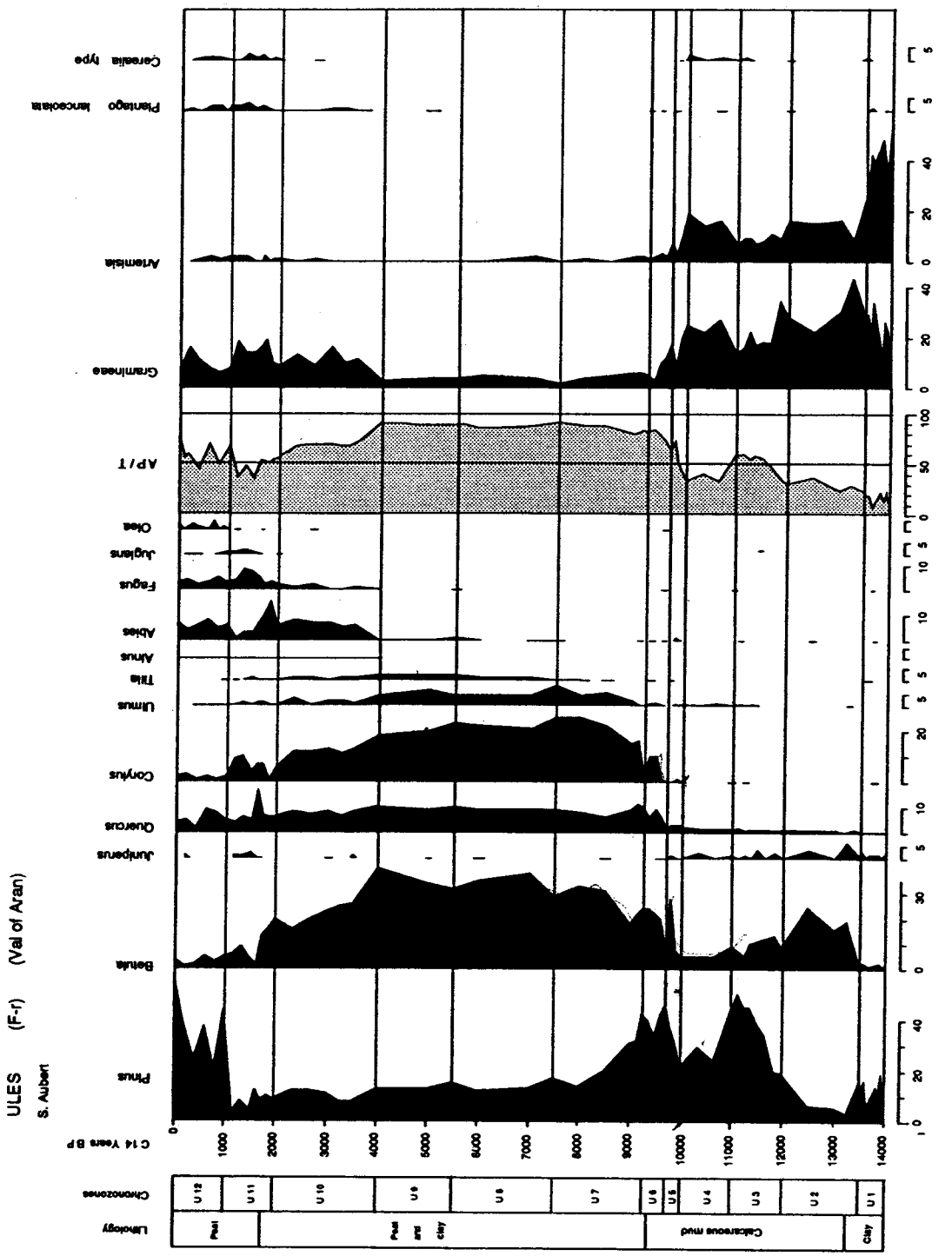


Fig. 17.31 Late-glacial and Holocene pollen diagram from the peat bog of Ules. Only selected pollen types are shown

On many slopes, meadows and coppices with hazel and birch replace the beech–fir forest. In other situations, beech–fir forest is well developed and devoted to forestry. On the south-facing slopes of the sheltered valleys a *Pinus sylvestris* forest takes the place of the beech–fir forest. Subalpine *Pinus uncinata* forest is frequently destroyed.

Soils: Alpine soils, forest brown soils, some leached soils.

Land use: Large uncultivated areas, some forestry, forests, pasture.

Reference site 22. Peat bog of La Bassa d'Ules (Val of Aran, Spain) (Aubert 1993)

Latitude 42°44'N, Longitude 4°26'E. Elevation 1650 m. Age range 14000–0 BP. 12 local pollen assemblage zones (paz). (Fig. 17.31)

	Age	Local paz
U 1	14000–13500 BP	*Artemisia*–Gramineae–*Pinus*
U 2	13500–12000 BP	Gramineae–*Artemisia*–*Betula*
U 3	12000–11000 BP	*Pinus*–Gramineae–*Betula*–*Artemisia*
U 4	11000–10000 BP	*Pinus*–Gramineae–*Artemisia*
U 5	10000–9700 BP	*Pinus*–*Betula*–Gramineae–*Quercus*–*Artemisia*
U 6	9700–9300 BP	*Pinus*–*Betula*–Gramineae–*Corylus*–*Quercus*
U 7	9300–7500 BP	*Betula*–*Corylus*–*Pinus*–*Quercus*–*Ulmus*
U 8	7500–5500 BP	*Betula*–*Corylus*–*Pinus*–*Quercus*–*Ulmus*–*Tilia*
U 9	5500–4000 BP	*Betula*–*Corylus*–*Pinus*–*Quercus*–*Ulmus*–*Tilia*–*Abies*
U 10	4000–2000 BP	*Betula*–*Corylus*–Gramineae–*Abies*–*Pinus*–*Fagus*
U 11	2000–1000 BP	Gramineae–*Corylus*–*Pinus*–*Quercus*–*Abies*–*Fagus*–Cerealia–*Juglans*
U 12	1000–0 BP	*Pinus*–Gramineae–*Quercus*–*Abies*–*Fagus*–*Olea*

General remarks on the pollen diagram

- Around 14000 BP absence of *Juniperus* phase but clear decrease in the *Artemisia* values.
- Continuous presence of *Quercus* and occurrence of *Ulmus* during the Younger Dryas.
- Presence of Cerealia pollen type which could be due to the local presence of Gramineae such as *Glyceria fluitans*.
- Local low representation of *Alnus* and *Fraxinus*.
- Constant local abundance of *Betula* and *Corylus* from the beginning of the Post-glacial to the beech–fir forest expansion.
- With respect to the data obtained in the more eastern sites, late expansion of *Abies* near 3600 BP synchronous with that of *Fagus*. Synchronous increase in Gramineae values and anthropogenic indicators more abundant.
- Continuous curve of *Olea* near 1000 BP (Galop, unpublished) reflects the spread of olive cultivation in Spain (Riera-Mora & Esteban-Amat 1994).

TYPE REGION F-r, WESTERN PYRENEES

Altitude: 400–3355 m.

Climate: Oceanic. High precipitation with maximum in spring, autumn, and winter.

Geology: In the central part of the chain, igneous rocks (dacite, andesite, and granite) along with Palaeozoic limestone and schist. To the north at middle elevation, Urgo-Aptian limestone of the Mesozoic sedimentary mantle.

Topography: Complex. Great diversity of situations, from high summits with some restricted glaciers to hills of the piedmont.

Population: Concentrated in villages and small towns in the valleys and in some larger towns on the piedmont.

Vegetation: A complete succession, from the low-altitude zones to the alpine zone. On the hills of the piedmont up to 1400–1500 m: deciduous oak forests. At higher elevations, *Fagus* is dominant, along with *Abies* near its western limit. In the subalpine zone, from 1700 to 2500 m, some forests and stands of pine (*Pinus uncinata*), which is also close to its western limit. Great extent of pasture.

Soils: In the mountain part, alpine and pseudo-alpine rankers as well as acid and eutrophic brown soils. Rendzinas on the Mesozoic limestone. To the north, leached soils and podzols.

Land use: Some forestry in the mountain zone but essentially dominance of pastures and uncultivated areas.

Reference site 20. Peat bog of Estarrès
(Andrieu 1987, Jalut *et al.* 1988, Jalut *et al.* 1992, Andrieu *et al.* 1993)

Latitude 43°5′43″N, Longitude 0°24′46″W. Elevation 376 m. Age range 13000–0 BP. 13 local pollen assemblage zones (paz). (Fig. 17.32)

	Age	Local paz
E 1	13000–12800 BP	Gramineae–*Artemisia*–*Betula*–*Pinus*
E 2	12800–12000 BP	Gramineae–*Betula*–*Artemisia*–*Pinus*
E 3	12000–11000 BP	Gramineae–*Pinus*–*Betula*–*Artemisia*–*Quercus*
E 4	11000–10000 BP	*Pinus*–*Betula*–Gramineae–*Artemisia*–*Quercus*
E 5	10000–9500 BP	*Pinus*–Gramineae–*Betula*–*Quercus*–*Artemisia*
E 6	9500–9000 BP	*Pinus*–Gramineae–*Quercus*–*Corylus*
E 7	9000–8200 BP	*Quercus*–*Corylus*–*Pinus*–Gramineae
E 8	8200–7000 BP	*Quercus*–*Corylus*–*Pinus*–Gramineae–*Ulmus*
E 9	7000–6000 BP	*Corylus*–*Quercus* – Gramineae–*Pinus* – *Ulmus* –*Alnus* –*Tilia*
E 10	6000–5000 BP	*Corylus*–*Quercus*–*Alnus*–Gramineae–*Fraxinus*
E 11	5000–4000 BP	*Corylus*–*Alnus*–*Quercus*–*Abies*–*Fagus*–*Castanea*
E 12	4000–2000 BP	*Alnus*–*Corylus*–*Quercus*–*Fagus*–*Abies*–*Castanea*–*Vitis*–Cerealia
E 13	2000–0 BP	*Alnus*–Gramineae–*Corylus*–*Quercus*–*Fagus*–*Abies Castanea*–*Vitis*–*Juglans*–Cerealia–*Secale*

General remarks on the pollen diagram

- Absence of *Juniperus* phase in the pollen diagram prior to 13000 BP but presence in a new study of the site (Andrieu *et al.* 1993).
- Until 11500–11000 BP the vegetation was open. Then forest expanded, as indicated regionally by the changes in the fauna (Bahn 1982).
- The continuous curve of *Quercus* begins during E 3 paz and can be correlated with Allerød.
- Younger Dryas correlated with E 4 paz is not strongly marked. Its beginning is dated 11130 ± 200 Gif 8784. The values of *Quercus* do not decrease during this phase.
- As at the other sites, *Quercus* expands some centuries before *Corylus*.
- The beginning of the continuous curve of *Ulmus* is dated 8170 ± 80 Gif 8177. The first pollen of *Tilia* is present between 9500 and 8200 BP. Its curve is continuous near 6000 BP.
- The expansion of *Alnus* and *Fraxinus* occurs after 6000 BP.
- The continuous curves of *Abies* and *Fagus* begin between 5000 and 4000 BP, but some pollen is present near 6000 BP. Significant values of *Fagus* are recorded in the nearby site of Castet (altitude 850 m) near 7000 BP, with some pollen of *Fagus* (Jalut *et al.* 1988).
- Locally the first anthropogenic indicators appear between 5000 and 4000 BP (*Plantago lanceolata*: 4860 BP; *Castanea* : 4300 BP; Cerealia and *Vitis*:

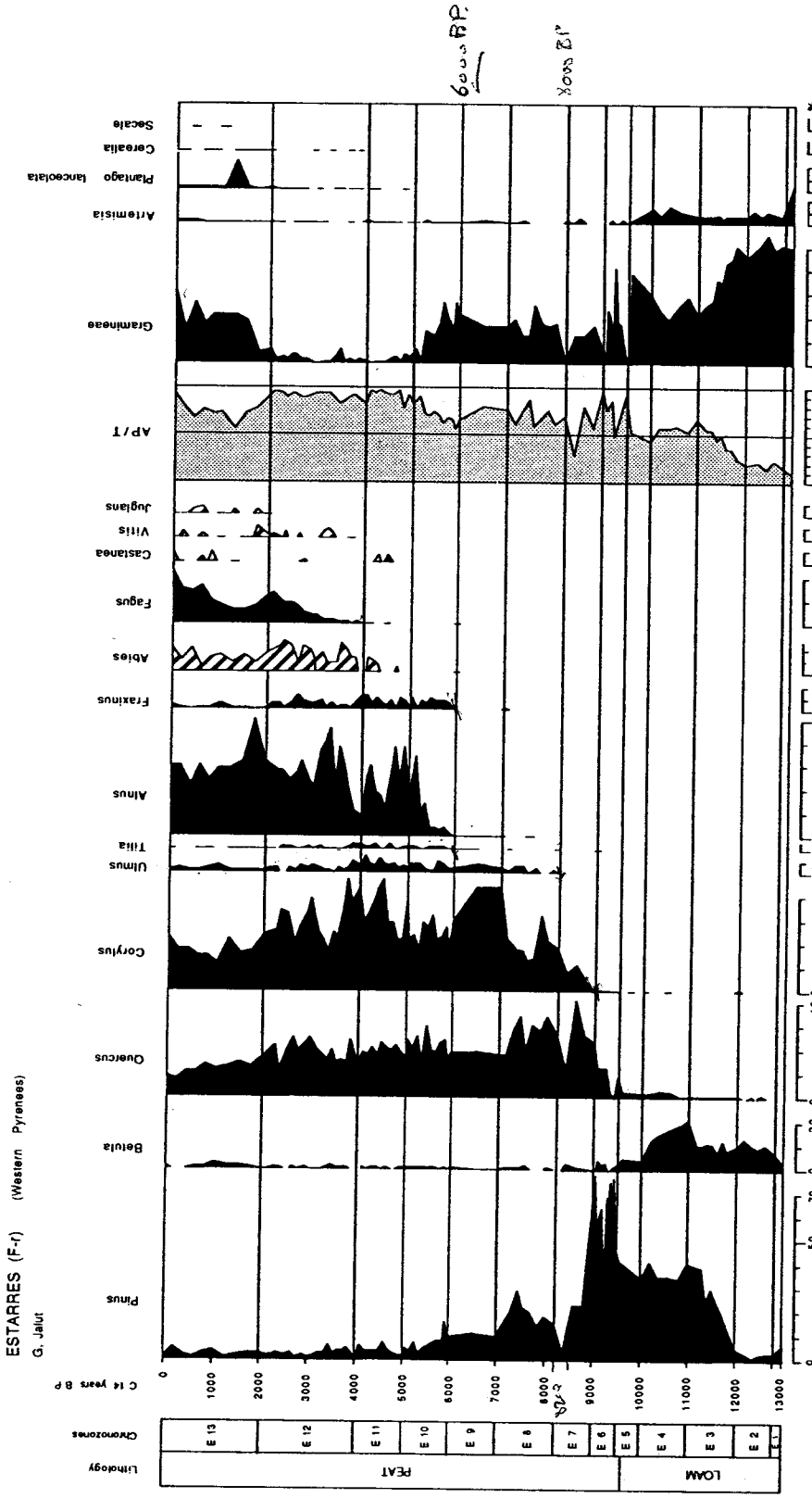


Fig. 17.32 Late-glacial and Holocene pollen diagram from the peat bog of Estarres. Only selected pollen types are shown

4000 BP). The beginning of the *Juglans* curve is dated 2060 BP.

PALAEOECOLOGICAL PATTERNS AND EVENTS WITHIN THE TYPE REGIONS F-zg AND F-r

History of the trees

Fig. 17.33 shows the relations among the five sites. However, it cannot reflect all the features of each type region in which several sites were studied by various authors and from which a more general chronological approach can be made. Taking into account all the available chronological data, Fig. 17.34 reviews the main published results.

Common patterns

- In each type region, a transition phase dominated by *Juniperus* is recorded Its beginning is well dated at La Borde (13630 ± 230 Gif TAN,) thanks to one ^{14}C AMS date on macroremains of the moss *Pohlia annotina* (Hedw.) Lindb.). At Freychinède (Jalut *et al.* 1992) the same event is dated between 14700±800 and 14500±570 and on the piedmont of Lourdes (Biscaye, Mardonès & Jalut 1983) between 14820±240 and 13250±120. It is contemporaneous with the decrease in *Artemisia* values dated 13490±220 at Barbazan in the Garonne valley (Andrieu 1991). For the same site this *Juniperus* phase can be recorded in one sedimentary sequence and not in another (e.g. La Borde, Reille 1990a, Jalut *et al.* 1993). The *Juniperus* maximum can be prior to or contemporaneous with the expansion of *Betula* at the beginning of the Late-glacial period around 13500 to 13000 BP.
- Younger Dryas is recorded in all type regions.
- *Quercus* was present early during the Late-glacial, especially from Allerød (Jalut *et al.* 1992). Scarce pollen present during the Bølling.
- At the beginning of the Post-glacial *Quercus* expanded about two or three centuries before *Corylus*.
- The presence of *Fagus* is commonly recorded between 5300–5200 BP and 4500 BP, but its expansion occurred around 4000 BP. If it depends chiefly on climatic conditions, local asynchronisms are due to differences in periods and systems of exploitation of the landscape (Galop & Jalut, unpubl.).

Unique patterns

- *Populus* is noticed in the eastern Pyrenees (Reille 1990b, Jalut *et al.* 1992). Its first occurrence is dated about 8700 ±140 BP (Jalut *et al.* 1992).
- The history of *Abies* is very different, depending on the areas considered.
  - In some sites of the eastern Pyrenees it is found from 10000 to 9500 BP (Nohèdes, Jalut 1974) or near 9150±250 (Gourg Nègre, Reille & Lowe 1993). But its regular presence can be documented near 8650–8270 BP (Jalut *et al.* 1992). Then its expansion occurred between 8300 and 7500 BP (Figs 17.34 and 17.35).
  - To the west at Freychinède and l'Estagnon, the beginning of its expansion is differently dated according to the sequences studied (Freychinede: 7030±140, Jalut *et al.* 1982; 8560±200, Reille 1993b; l'Estagnon: 6690±70, Reille 1993b) (Fig 17.36).
  - In the Central Pyrenees, the dates obtained, at low and medium elevation, for the *Abies* expansion are similar: Barbazan 450 m, 3640±60 (Andrieu 1991); Ules 1650 m, 3600±65 (Aubert 1993). *Fagus* spreads at the same time (Fig. 17.37).
  - In the Western Pyrenees, near its present western limit, the development of *Abies* is dated near 4900–4800 BP with some isolated pollen near 7000 BP. (Castet, Jalut *et al.* 1988). *Fagus* appears between 4800 and 4300 BP (Fig. 17.38). These data show the strong gradient of development of *Abies* between the Atlantic and the Mediterranean. On the basis of the available data, the central part of the northern Pyrenean slope seems to be a transition zone between two types of Holocene history for *Abies*.
- A first significant occurrence of *Fagus* is noticed in

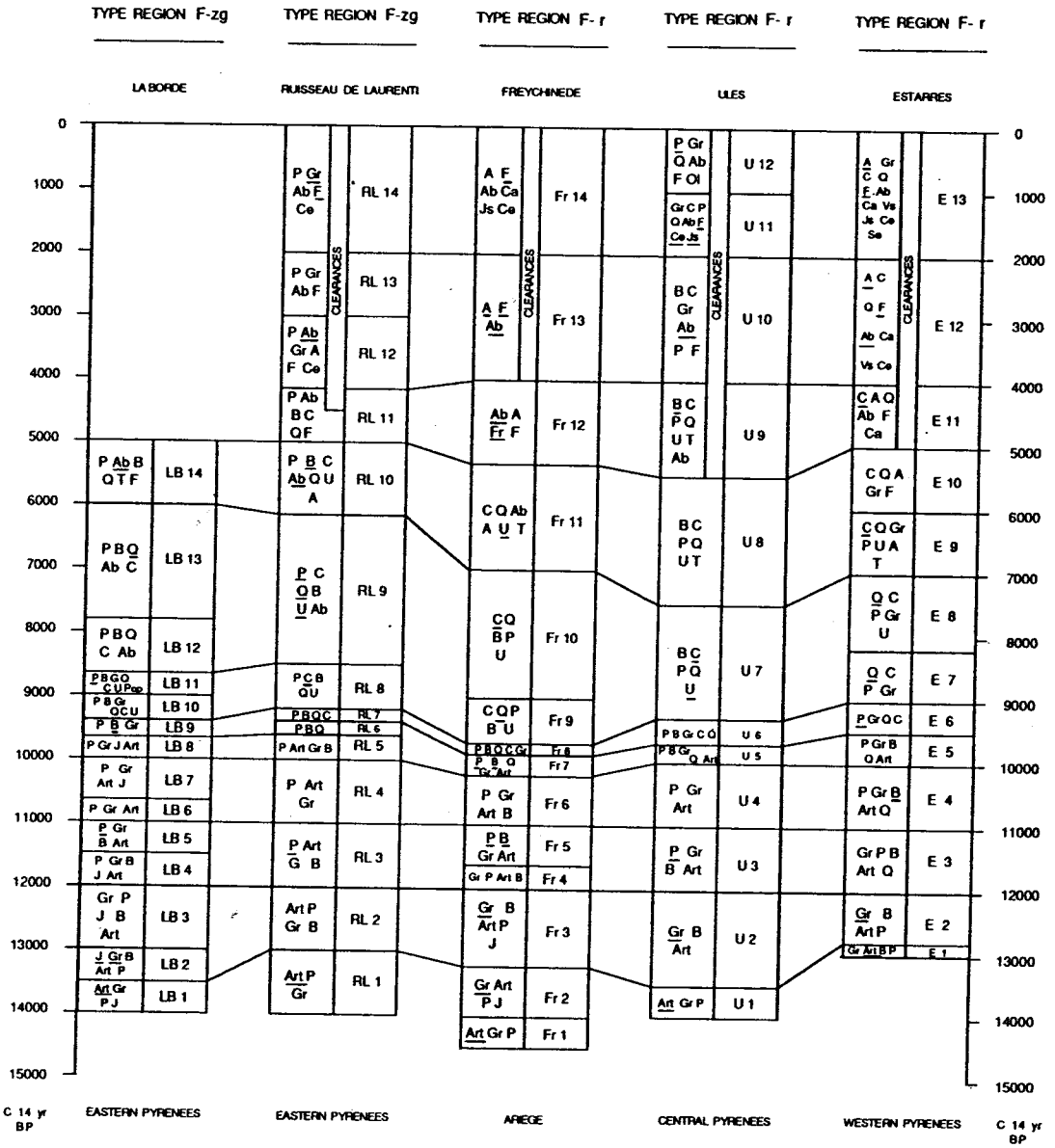


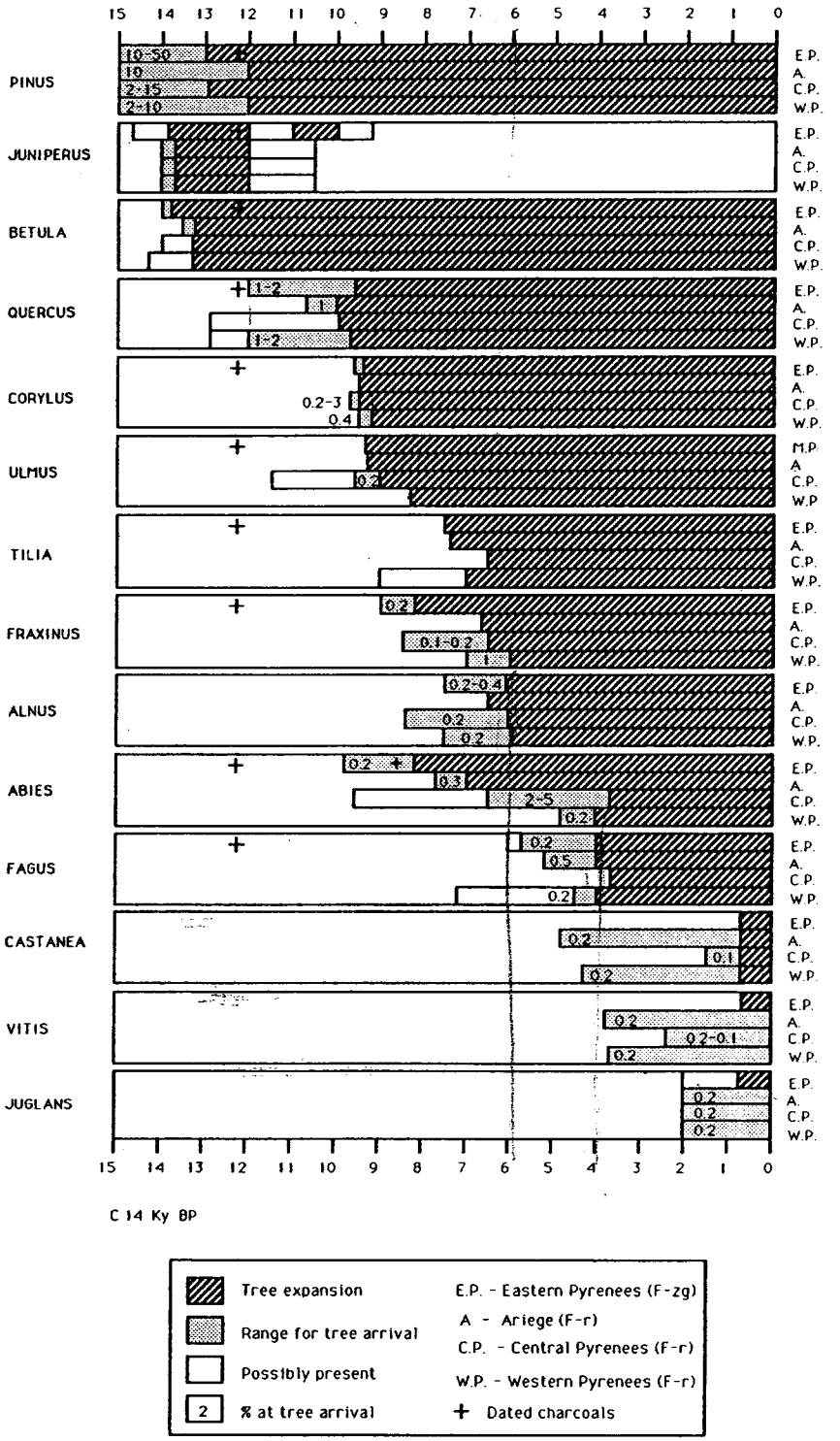
Fig. 17.33 Time–space correlation of local pollen-assemblage zones A = *Alnus*, Ab = *Abies*, Art = *Artemisia*, B = *Betula*, C = *Corylus*, Ca = *Castanea*, Ce = Cerealia, F = *Fagus*, Fr = *Fraxinus*, Gr = Gramineae, J = *Juniperus*, Js = *Juglans*, P = *Pinus*, Q = *Quercus*, Se = *Secale*, T = *Tilia*, U = *Ulmus*, Vs = *Vitis*. (Underlined: maximum phase)

some sites of the western Pyrenees around 7000 BP, but this species did not develop and only extended from 4500 to 4200 BP at low elevation in the oak forest and at medium elevation at the expenses of *Abies*.

Anthropogenic events

Unique patterns

The earlier anthropogenic indicators and clearances were observed on the northern slope of the eastern


15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
PINUS
10-50
10
2-15
2-10
JUNIPERUS
BETULA
QUERCUS
1-2
1
1-2
CORYLUS
0.2-3
0.4
ULMUS
0.2
TILIA
FRAXINUS
0.2
0.1-0.2
1
ALNUS
0.2-0.4
0.2
0.2
ABIES
0.2
0.3
2-5
0.2
FAGUS
0.2
0.5
1
0.2
CASTANEA
0.2
0.1
0.2
VITIS
0.2
0.2-0.1
0.2
JUGLANS
0.2
0.2
0.2
E.P.
A.
C.P.
W.P.
M.P.
C 14 Ky BP
Tree expansion
Range for tree arrival
Possibly present
2 % at tree arrival
E.P. - Eastern Pyrenees (F-zg)
A - Ariege (F-r)
C.P. - Central Pyrenees (F-r)
W.P. - Western Pyrenees (F-r)
+ Dated charcoals

Pyrenees around 6100 BP, e.g. peat bogs of Ruisseau de Fournas 1510 m and Pinet 880 m (Jalut 1974, Jalut & Vernet 1989, Reille 1990b) and subsequently confirmed by the discovery of domestic fauna in the Cave of Dourgne in the same valley 10 km to the north (Geddes 1980) (Fig. 17.33).

In the high valley of Têt (La Borde) open wide to the Mediterranean, very regular occurrences of Cerealia pollen type are found from 8700 BP, associated with Chenopodiaceae, Cichorioideae, *Pistacia*, *Buxus*, and *Quercus ilex* type. Except for Cerealia, this pollen assemblage was also found in the first study of La Borde (Jalut 1971), with in addition an increase in *Artemisia* and *Rumex* values between 8300 and 7500 BP. It is clearly older than the first sporadic human clearances recorded between 7000 and 3000 BP on the Catalan coast (northeastern Iberian Peninsula) at the southeastern extremity of the Pyrenees (Riera-Mora & Esteban-Amat 1994). In the site of Ules, when the human impact becomes obvious in the upper zones (U 10 to U 12) with the classical presence of apophytes and anthropochores, we do not observe, as in other sites of the northern slope, the classical strong increase in *Fagus* values. On the contrary, it is at that time that *Pinus* expands. If in the northern Pyrenean slope the human activity was responsible for the *Fagus* extension (Jalut 1984), it seems in the light of this example that on the southern slope or on south-facing slopes of sheltered valleys *Pinus* was also favoured by the same phenomenon and that its present importance in such exposures must be partly related to human impact from the Bronze Age onwards.

Common patterns

In the two type regions, human influence became important between 5000 and 4000 BP. In the mountains, its general consequence was a strong decrease of *Abies* and the expansion of *Fagus* (Jalut 1984, Jalut *et al.* 1984), which continued during historical time (Fruhauf 1980).

In the Ariege and western Pyrenees, where they are well dated, the first pollen of *Castanea* is found between 4820 and 4310 BP, *Vitis* between 3800 and 3680 BP, and *Juglans* between 2060 and 2020 BP (Figs 17.35 and 17.36). Great differences exist for the beginning of the development of the same species, according to the area and the altitude, e.g. the regular presence of *Juglans* does not necessarily correspond to the Roman age (Pla de l'Orri, Cerdagne, near La Borde, 760 ± 50; Canet, Mediterranean coast, 700 ± 70 (Planchais 1985); Pailhères near Ruisseau de Laurenti, 1100 ± 70; Argentière, near Freychinède, 1850 ± 50, Galop, unpublished).

Climatic events

The end of the glacial period

The most important climatic change is reflected in the two type regions as well as in the southwestern Spanish part (Montserrat Marti 1991) by the well-dated *Artemisia* decrease and *Juniperus* expansion (La Borde: 13630±230 Gif TAN, Jalut *et al.* 1992). Due to the present distribution of *Juniperus thurifera* in northern Spain (valley of Ebro and Sierra de Alcubiere, Puerto de Somosierra to the north of Sierra de Guadarrama, northeast of Leon in the southern slope of the Cantabric Mountains), as well as in the French Pyrenees (valleys of Garonne and Ariege), it can be assumed that this species was a component of the vegetation cover during the *Juniperus* phase from about 14000 BP to about 13500–13000 and probably up to 10000 BP, with a significant presence during the Younger Dryas and the beginning of the Post-glacial in the Mediterranean Pyrenees. The Ephedro–Juniperetalia, pre-steppe formation described in the High Atlas Mountains (Morocco) (Quezel & Barbero, 1981, 1986), has its optimum development under Mediterranean climatic conditions, where annual precipitation is 250–500 mm. With respect to the phase 15000–14000 BP not described here, with low *Juniperus* values and strong representation of Chenopodiaceae, *Artemisia*, and Gramineae, the *Juniperus* phase can be considered as a period of increase in temperatures (summer and winter) and precipitation (Jalut *et al.* 1992). This climatic trend continues during the Bølling.

Fig. 17.34 Tree arrival and tree expansion in the French Pyrenees

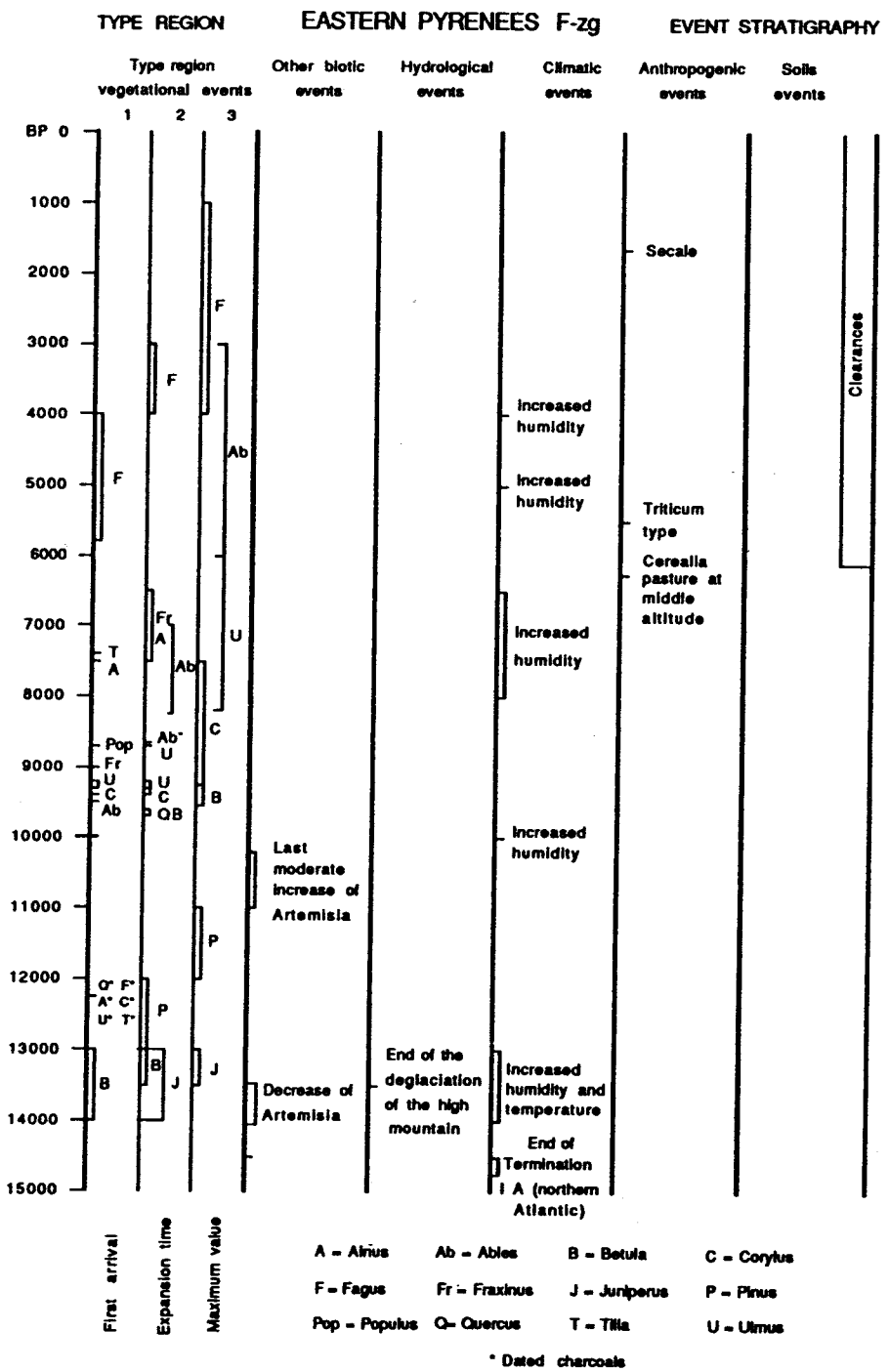


Fig. 17.35 Event stratigraphy in type region F-zg (Eastern Pyrenees)

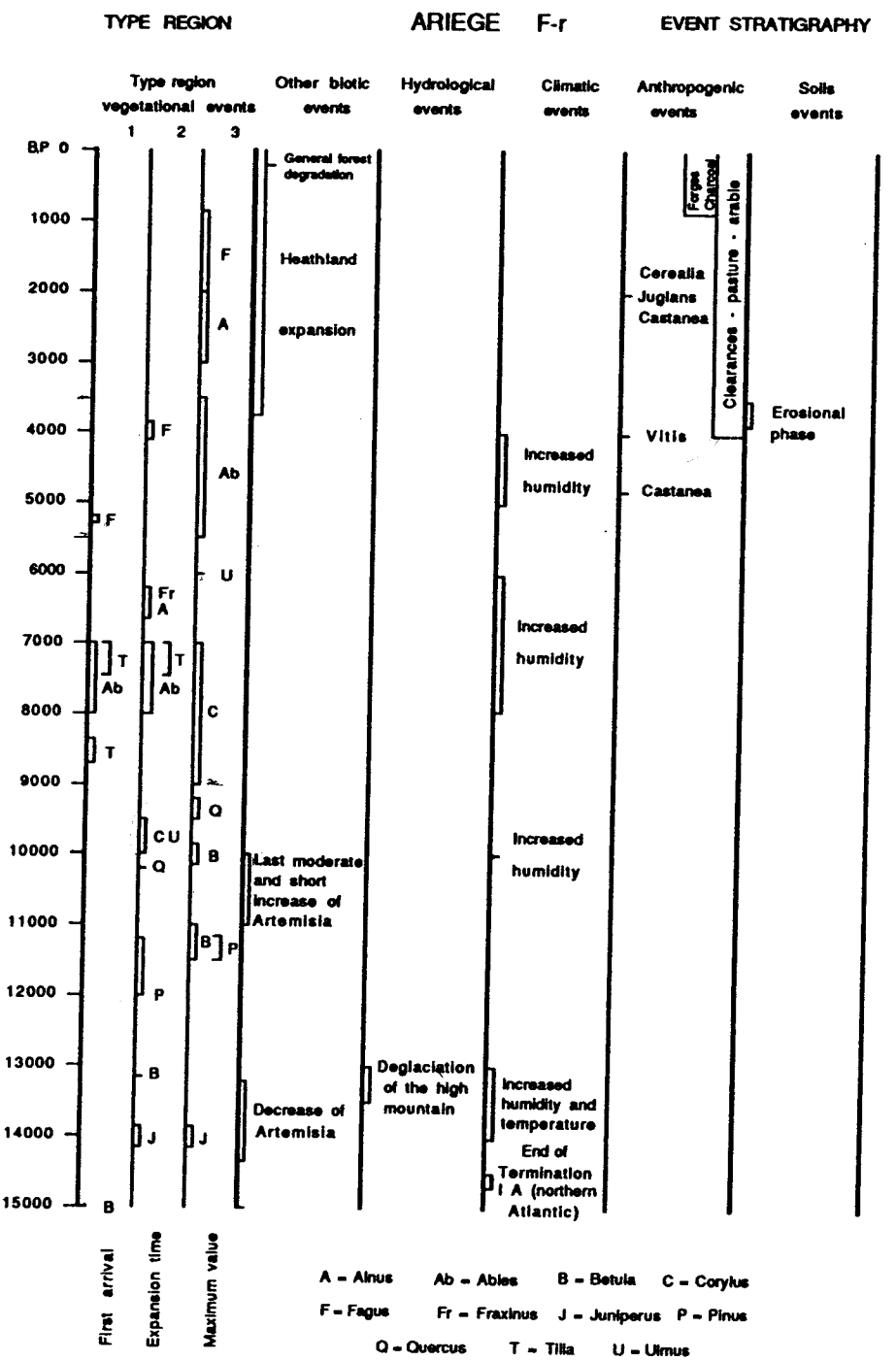


Fig. 17.36 Event stratigraphy in type region F-r (Ariege)

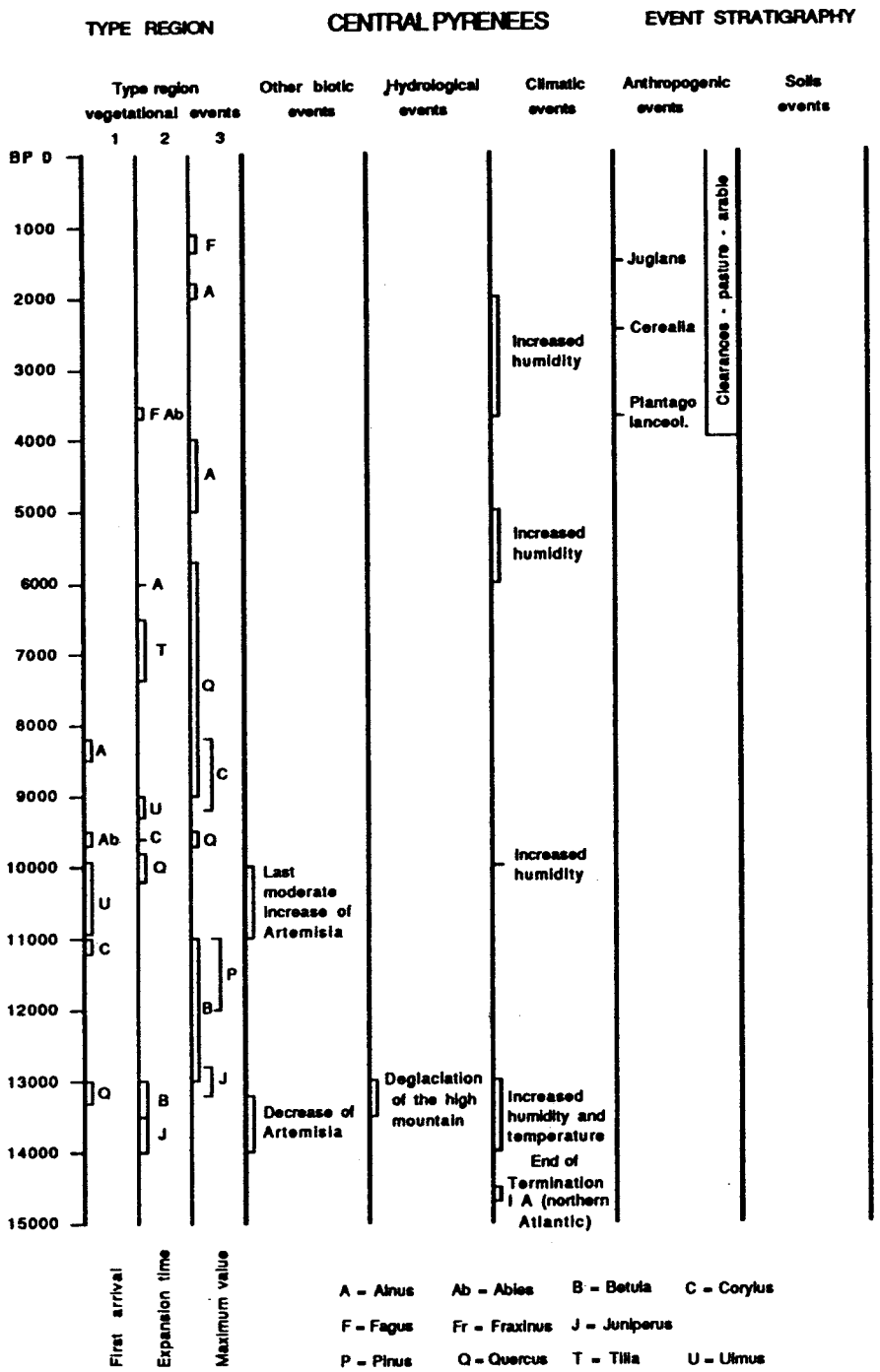


Fig. 17.37 Event stratigraphy in type region F-r (Central Pyrenees)

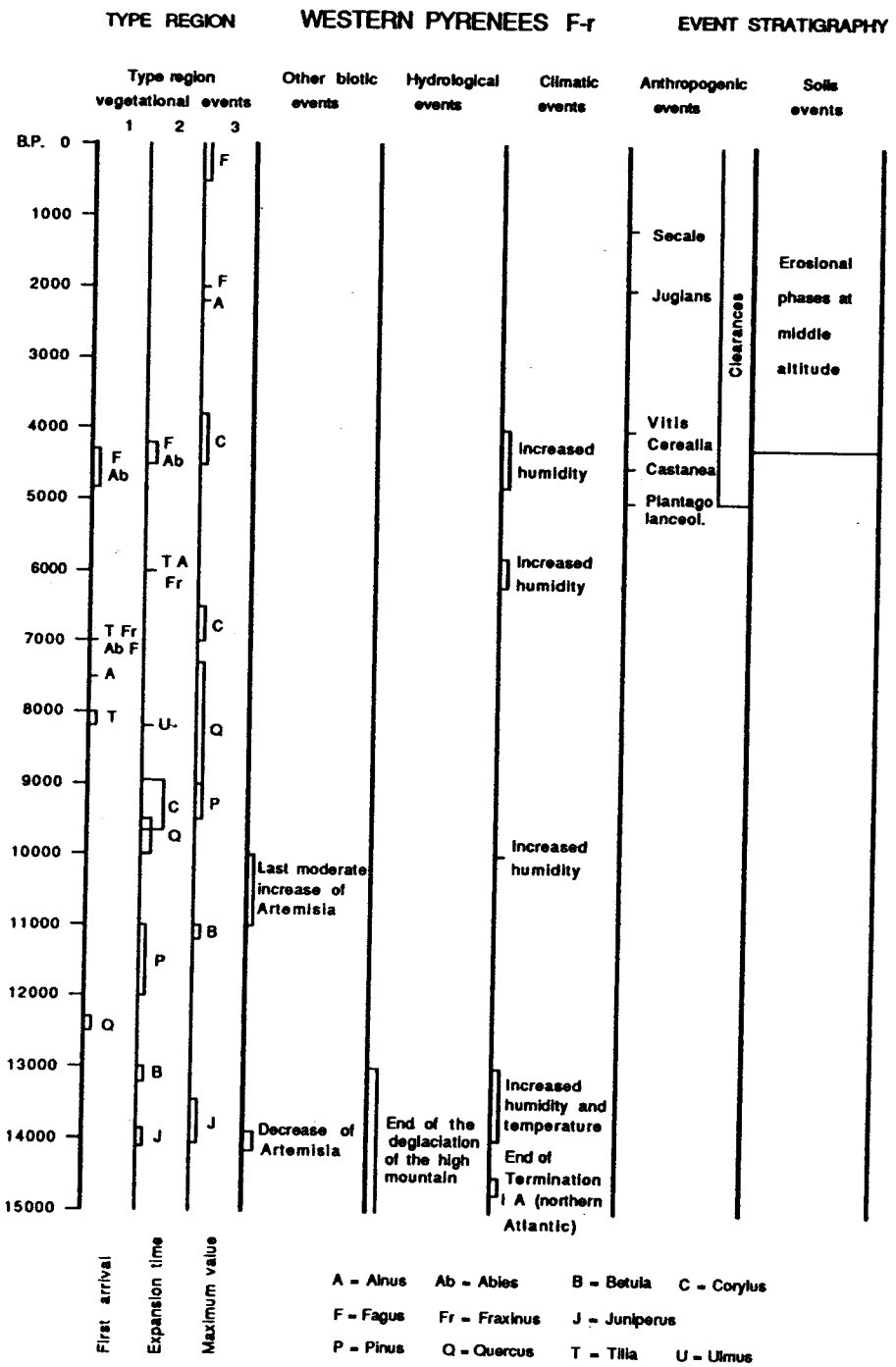


Fig. 17.38 Event stratigraphy in type region F-r (Western Pyrenees)

The Late-glacial period

Its beginning around 13500–13000 BP corresponds to the *Betula* expansion (beginning of the Bølling–Allerød period). It is followed by the spread of *Pinus* between 12200 and 11000 BP. The Younger Dryas is clearly characterized by a new development of the heliophilous taxa. Its beginning is dated 11130±200 at Estarrès. Its impact on the representation of *Quercus*, still regularly present from the Allerød period, is very limited or not visible.

The Post-glacial period

Its beginning could be dated near 10200–10100 BP (Jalut *et al.* 1982, Mardonès & Jalut 1983). *Pinus* and *Betula* are the dominant trees with steppe or heliophilous elements. *Quercus* then *Corylus* expand. The interval between the expansion of these trees (some centuries) could be related to the persistence of dry climatic conditions at the beginning of the Post-glacial, limiting the spread of other broad-leaved trees (*Corylus* and *Ulmus*) (Jalut *et al.* 1992).

An important change, interpreted as an increase in precipitation, occurred between about 8300 and 6500–6000 BP, when *Alnus*, *Fraxinus*, and *Abies* appeared or extended according to the geographical locations. In some sites of the western and Spanish Basque Country, the climatic change is marked by a short appearance of *Fagus* near 7000–6800 BP (Alimen *et al.* 1965, Penalba 1987, Jalut *et al.* 1988). No clear climatic modification is registered until 5200–4500 BP. From this period onwards *Fagus* began to expand, and *Abies* spread in the central and western Pyrenees. This reflects increasing precipitation and/or atmospheric humidity. Then, because of human influence, it is difficult to determine what in the *Fagus* development is due to climate and what results from human impact.

Soil events

In Ariège and western Pyrenees important erosional phases were recorded at middle altitudes from 4000 BP onwards (Jalut *et al.* 1982, 1988). They are always correlated with deforestation.

TYPE REGION F-zd, CHAÎNE DES HURTIÈRES (F. David)

A recent paper has synthesized the palaeoecological investigations of the last 20 years in the French Alps and the Jura Mountains (Beaulieu *et al.* 1994). It shows that the vegetation history of large areas is unknown, preventing a detailed synthesis of the vegetation history for the French Alps.

If we consider the northern French Alps only, nine important massifs extend over 140 km from north to south and 80 km from west to east (Fig. 17.39). The elevation varies between 200 m and 4800 m.

The major present ecological subdivisions in the area are linked primarily to increasing continentality (three zones: outer, intermediate and inner Alps are distinguished from west to east) and secondarily to increasing altitude. Hill, mountain, subalpine, and alpine vegetation belts have increasing altitudinal limits with increasing continentality. A complete palaeoecological reconstruction should take into account these different ecological parameters without ignoring local parameters such as exposure.

This contribution attempts to illustrate the methodological approach we need to reach such a palaeoecological synthesis, considering a whole limited mountain as a "key-massif". We present here five of the six studied sites in different vegetation belts of the Chaîne des Hurtières. This mountain extends over 15 km from southwest to northeast and 7 km from west to east. The highest point is around 2000 m, the lowest 150 m. Included in zone F-zd, the chain is at the very limit with zone F-zb1 and must be linked to the intermediate Alps (Fig. 17.40).

Climate: The mean annual temperature varies between 11°C in the valley and 4°C in the subalpine belt. Precipitation increases with altitude, around 1200 mm in the mountain belt and 1600 mm in the subalpine belt. The snow cover in the subalpine belt lasts for 3 to 5 months.

Geology: The Chaîne des Hurtières extends to the north into the crystalline Belledonne massif. The western side of the Chaîne des Hurtières presents a tectonic contact between the mica-schist axis and the Jurassic schist and the calcareous sedimentary cover (Bajocian). The relief is smooth.