A long Upper Pleistocene pollen record from Les Echets, near Lyon, France

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Analysis of 732 samples through 39 m of sediments from the ancient lake of Les Echets, 15 km northeast of Lyon, France, resulted in a long, continuous pollen diagram covering the interval from the Late Rissian to the Holocene. Above a complete Eemian sequence, there are two Early Würmian temperate cycles (the older one including two climatic optima separated by a brief deterioration) with forest successions characterized by the spread of *Carpinus* at the end of the early temperate phase. These episodes, whose exact equivalents are found at Grande Pile in the Vosges area, are correlated with the Early Würmian trilogy Amersfoort–Brørup–Odderade of northern Europe. The absolute dates proposed for the Grande Pile sequence are accepted, whereas those for the three northern European stratotypes are rejected. The Early Würmian is thus placed between 115,000 and 70,000 years B.P. In the Middle Würm, three undated interstadials are characterized by a sparse forest cover. The long Late Würmian section is a characteristic feature of the sediment history at Les Echets. Very cold and arid conditions prevailed during this interval, without any unequivocal indications of interstadial episodes. A rise in *Artemisia* around 15,000 B.P. marks the transition from the Pleniglacial to the Oldest Dryas.

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On sentait sourdre, et vivre, et végéter déjà
Tous les arbres futurs, pins, érables, yeuses,
Dans des verdissements de feuilles monstrueuses;

(V. Hugo: Légende des Siècles II)

Les Echets mire, 15 km northeast of Lyon, extends over 1,300 ha in a closed basin of 4,100 ha. It lies in the southwestern part of the Dombes Plateau (Fig. 1), which was covered with the Rhône Riss glacier (Mandier in Beaulieu *et al.* 1980). The external moraines at the west of the mire are attributed to this glacier.

The Les Echets depression was dug by a tongue of the glacier. As the Würmian glacier stopped at the foot of the Dombes Plateau, information concerning all the periods after the Riss may be expected from the pollen and spore content of the filling of this depression.

The first pollen analyses of the Les Echets mire (Gourc 1936) provided, with 19 spectra, a pollen diagram which at that time was quite reliable. In 1980, 424 pollen spectra from four different borings (Beaulieu & Reille in Beaulieu *et al.* 1980) evidenced the Eemian as well as two other forest periods before the Würmian Pleniglacial. A synoptic diagram was published (E.R.A. 404 1980). Lastly, in 1981, nine pollen spectra recorded by Denèfle, undoubtedly of a Würmian age, were wrongly ascribed to the beginning of the Holocene (Billard & Denèfle 1981).

The present study is the result of the pollen analysis of a 57 m deep boring in the centre of the bog. Only the upper 39 m contained pollen. It was extracted from the argillaceous sediments by flotation on Thoulet solution (Goeury & Beaulieu 1979). A more classical method (treatment with HF and acetolysis) was used for the pollen enrichment of organic sediments.

Analysis has been made of 732 samples. The mean pollen sum of all the spectra slightly exceeds 300. In some fifty particularly poor levels it falls to 100. The basic sum used to calculate percentages includes the pollen grains and spores of all the vascular plants. For the sake of convenience, the spectra have been grouped in four pollen diagrams (Figs. 2–5).

Pollen zonation and vegetational history

The three forest periods that had been found previously (Beaulieu & Reille in Beaulieu *et al.* 1980) are again recognized. They are characterized by a complex forest evolution similar to that

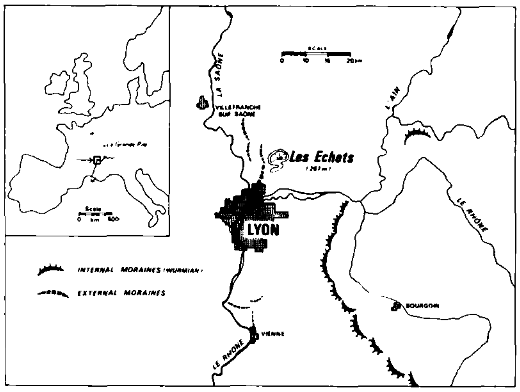


Fig. 1. Location of Les Echets.

of the Holocene. The oldest of these forest periods (between 36.6 m and 34.45 m) shows floristic characteristics *(Taxus, Buxus, Abies)* which clearly indicate the Eemian.

Zone A: end of the Riss

The end of the Riss glaciation is represented by a clay deposit corresponding to zone A, which has been subdivided into five subzones that reflect the steppic character of the vegetation.

Zone A1a, with fairly high frequencies of *Hippophaë* and *Juniperus,* may correspond to a weak interstadial unless it is only an artefact due to the beginning of pollen sedimentation.

Zone A1b certainly gives a good image of the vegetation at the end of the Rissian Pleniglacial. *Pinus* is practically the only arboreal type (with frequencies ranging between 25 and 30%) and is probably attributable to long-distance transport or to the local production of a few individuals. The exclusively herbaceous regional vegetation is a steppe with Chenopodiaceae, *Helianthemum, Ephedra,* Compositae, Cyperaceae.

Zone A2 is characterized by a simultaneous rise of *Betula* and *Pinus* curves (zone A2a) followed by a strong expansion of *Juniperus* (zone A2b). The persistent maximum of *Pinus* in both zones (with frequencies rising from 25 to approximately 40%) shows that the tree must have played a part in the regional vegetation. Simultaneously, the pollen of some mesophilous trees, more especially *Quercus,* steadily appears in the spectra.

All these facts are not unlike the Bølling-Allerød botanical events at the end of the Würm, and must have had the same cause: a first warming that started pioneer dynamics in which *Betula, Juniperus* and *Pinus* played a role (in this case *Betula* precedes *Juniperus*).

Zone A2c is a Rissian homologue of the Younger Dryas, with the following characteristics: a fall in *Juniperus* and *Pinus* frequencies, a persistence of those of *Betula* and a rise of the NAP curve, especially *Artemisia* and Poaceae; they show the importance of arid and cold steppic formations in the regional vegetation. A vegetational diversification inherited from the preceding zone appears through the curves of Apiaceae, Ranunculaceae, Rubiaceae, Rosaceae, *Rumex, Sparganium* and *Typha.* The quite steady occurrence of *Cedrus* pollen in the spectra is due to long-distance transport, as in the Würmian Lateglacial and at the beginning of the Holocene (Beaulieu & Reille 1974).

Zone B: The Eemian

The Les Echets Eemian sequence is evidenced by 82 pollen spectra; it extends over 210 cm of sediments, 120 cm of which are organic lake mud. It lies between two glacial periods and shows a complete and typical vegetational evolution.

Zone B1. – The first sign of a great climatic change is the fall in *Artemisia* frequencies pointing to less arid conditions. This phenomenon is accompanied by an expansion of *Betula* and *Pinus.* A tall grass vegetation must have existed during this period, at least on the shores of the lake. It gradually disappeared, but traces are still found in zone B4.

Zone B2. – The major vegetational event is the extraordinary expansion of *Ulmus* simultaneously with the maximum of *Betula. Ulmus* is therefore the first mesophilous tree to know success; it reaches percentages of 37% never recorded up to now in Europe during the Holocene. *Quercus,* whose pollen is regularly recorded in the spectra as early as zone A2b, was certainly widely spread, contrary to *Ulmus* for which only occasional occurrences are noted since this period. Therefore the sudden expansion of *Ulmus* is probably due to the abundance and good dissemination of its fruit. *Pinus* begins to regress and disappears altogether at the end of B4.

Zone B3. – One observes the progressive disappearance of *Betula*, the decrease in *Ulmus* values and rise of the *Quercus* curve up to a maximum above 50%. *Fraxinus* and chiefly *Acer* are also increasing. The continuous curve of *Hedera* indicates the frequent presence of the species in the oak-forest. It suggests that this zone may correspond to the thermal optimum. One should also mention the absence of *Tilia* in this interglacial.

The first three zones of the Eemian are marked by fairly high herbaceous pollen percentages. *Rumex* and *Filipendula* pollen presumably reflects the presence of a tall grass vegetation on the shores of the lake. As regards *Artemisia*, Chenopodiaceae, *Helianthemum* and *Thalictrum*, two interpretations may be put forward: (1) a reworking of sediments from the very end of the Riss, consistent with the argillaceous nature of the sediment, and (2) a persistent aridity which made possible the survival of small areas with a steppic vegetation where *Juniperus* was present.

In zone B4 the expansion of *Corylus* takes place. The mass introduction of *Corylus* pollen grains in the pollen rain is probably the main cause of the decrease of *Quercus* relative frequencies, as shown by the fact that the usual associates (*Acer* and *Fraxinus*) of the oak forest are then at their maximum. It may be that *Quercus* did not lose ground, but that *Corylus* became more and more abundant in the oak forest. This spread of *Quercus* before *Corylus*, also found but to a less degree at the beginning of the Holocene, clearly indicates that *Corylus* did not play a pioneer role in the formation of the oak groves.

Just as in the Boreal of southeastern France (Beaulieu *et al.* 1982), during this phase some *Pistacia therebinthus* pollen grains are recorded which, considering the still open character of forest populations (the A.P. curve is still rising), reflect the presence of the taxon in circummediterranean regions. Therefore, a persistent forestless vegetation may be assumed, in which *Juniperus* and *Artemisia* are still present.

Zone B5 starts at the clay-dy interface corresponding to a relatively short hiatus, which still completely conceals the beginning of the *Carpinus* extension; the genus appears right away with percentages of 35%. Oak forests with abundant *Corylus* are considerably decreasing, *Acer* disappears from the spectra, *Hedera* becomes rare, *Fraxinus* is no more present with a continuous curve.

This zone, entirely dominated by the abundance of *Carpinus*, points to an increasing oceanity of the climate and may correspond to the climatic optimum: *Ilex* and *Taxus* pollen are regularly recorded. *Alnus* shows a continuous curve as well as *Buxus* whose values approximating 10% have seldom been recorded.

Thick forest formations now cover all the territory. The extremely rare occurrence of non-arboreal pollen reflects the importance of forests; even Poaceae are sometimes absent from the spectra. At the end of this zone the expansion of *Abies* begins; it is the first botanical sign of the climatic regression that is just starting.

B6 is the zone of main expansion of *Abies*. While the *Abies* curve is rising, *Carpinus* declines (B6a). *Buxus* and *Ilex* are still found in the spectra and *Taxus* even reaches a small maximum. *Viscum*, an undoubted Atlantic species, appears. At the end of this zone, *Carpinus* formations have completely vanished and the expansion of *Picea* and *Pinus* (B6b) indicates that the climatic deterioration is still progressing.

In B7, Abies declines before *Picea* and *Pinus*, Pinus again reaching its highest frequencies since the end of the Riss. *Betula* reappears after a long eclipse.

In B8, there is a strong decline of *Pinus* and new extension of *Abies*. *Picea*, which requires less humidity and is well established, is not affected. Also noticeable is the modest presence of *Fagus*, which has not yet been found, a slight revival of *Carpinus* and *Quercus* and a rather shy appearance of *Buxus* and *Taxus*.

All these facts indicate a remission in the continental evolution of climate. Thus, the climatic regression which marked the end of the Eemian was neither continuous nor very rapid. The undisturbed organic sedimentation excludes the idea that this episode may result from a reworking of sediments from zone B6.

In B9 the sediment is not purely organic, silt is mixed to dy. *Abies* and *Picea* values suddenly fall. The Eemian ends with a new optimum of *Pinus* whose frequencies approximate 50%, and of *Betula*; the increasing percentages of *Artemisia* announce a new glacial epoch.

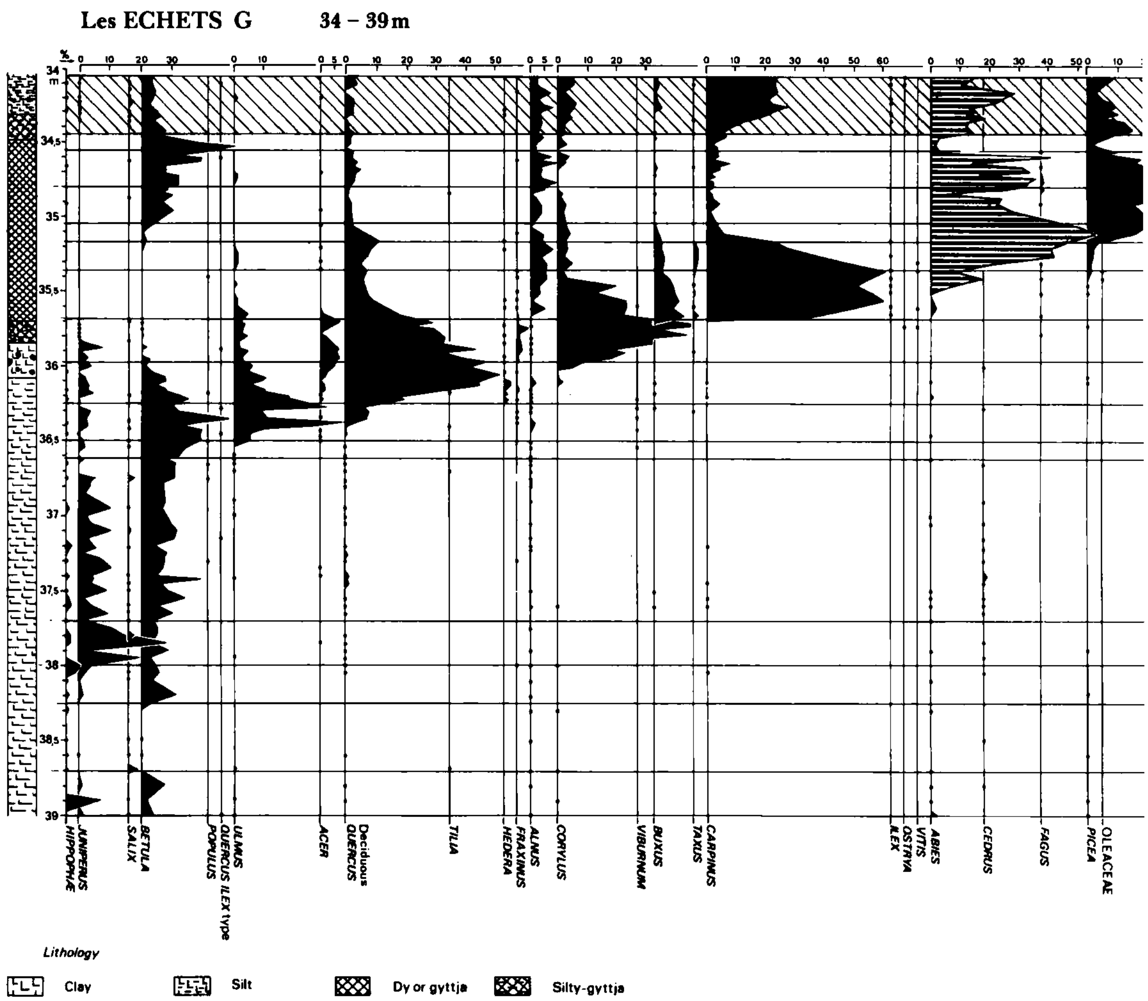


Fig. 2. Les Echets G: the lowest part (34–39 m) of the pollen sequence.

Zone C

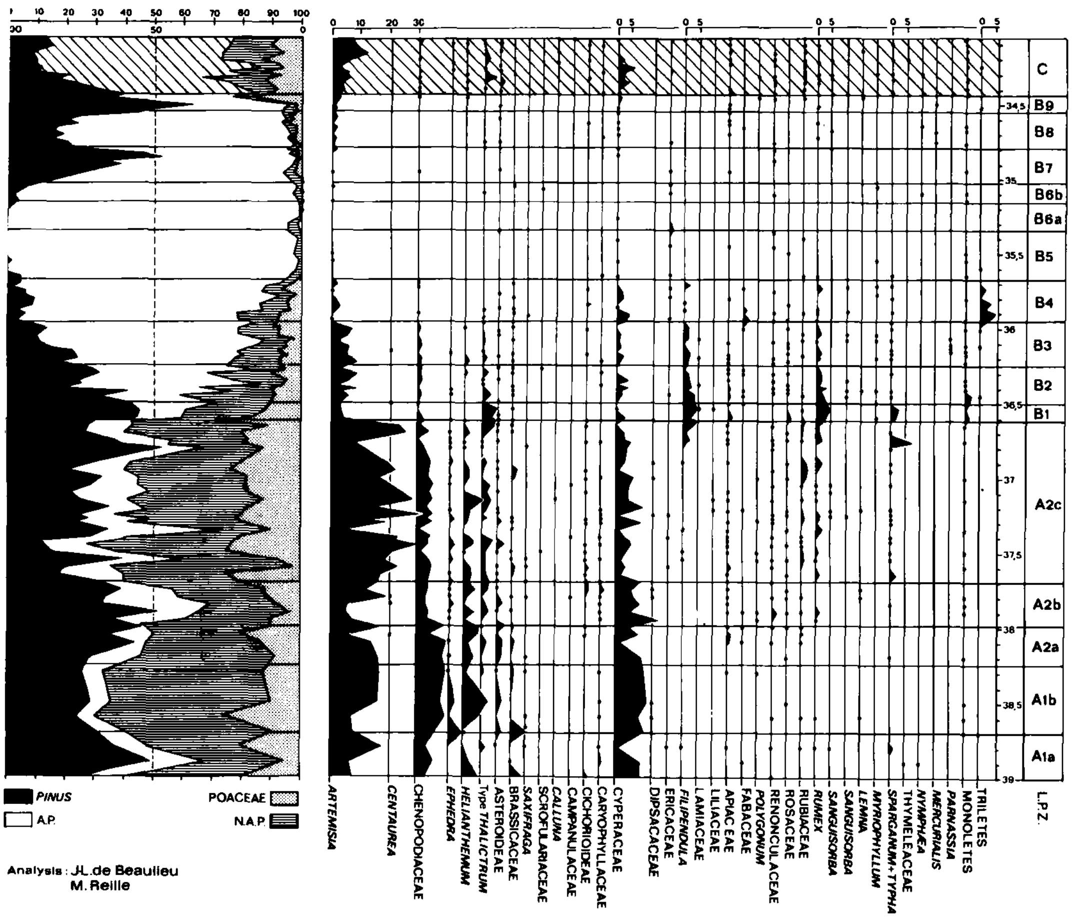
Zone C overlaps Figs. 2 and 3. The spectra are essentially characterized by the mixture of pollen of all the trees and all the herbaceous species, with an equal proportion of Poaceae pollen and steppe species pollen. This assemblage cannot be explained but by a rebedding of pollen from Eemian zones during a cold episode, as is suggested by the numerous dy granules encased in silty sediments.

The zones that can be established on the basis of the pollen curves, and are as a whole comprised between 34.5 m and 33.8 m, are but the result of the regressive reworking process (the levels with *Abies* and *Picea* are first rebedded, then those with *Carpinus* and *Buxus*), and have no vegetation historical significance whatever.

Zone D

Between 33.80 and 32.15 m, in a thick dy layer, a temperate forest cycle is recorded that enables one to distinguish eleven pollen zones, the very first steps of reafforestation being obviously obliterated by the last reworkings that characterize zone C.

D1. – *Pinus* and *Betula* are abundant, *Quercus* values increase and become the highest; *Viburnum* is present; there is also a curve of *Tilia*, which was very rare during the Eemian. The high percentages of *Fraxinus*, whose role was very



modest during the Eemian, is the main characteristic of this zone. *Ulmus* is moderately represented, *Abies* and *Carpinus* pollen are due to a rebedding.

D2. – *Corylus* reaches high frequencies (40%) and becomes dominant with *Quercus*. *Pinus* is disappearing. *Carpinus* is probably absent. At the beginning of this zone, a very short phase with Poaceae may be interpreted as a local event that does not affect the progress of forest evolution. Zone D2 ends with a sudden collapse of the pollen curves of all the arboreal species, thereby indicating the existence of a hiatus.

It should be noted that in D1 and D2, the successive establishment of *Quercus* and *Corylus* follows the Eemian pattern. This is the only likeness with the Eemian, as *Ulmus* is very modest here, whereas a clear maximum of *Fraxinus* accompanies the *Quercus* phase. The abundance of *Quercus* and *Corylus* pollen (75% in D2) provides evidence of the markedly temperate character of the climate. However, the very small amount of *Hedera*, *Buxus* and *Viscum* pollen suggests climatic conditions less favourable than during the preceding interglacial. The differences between this phase and the beginning of the Eemian may undoubtedly be accounted for by the characteristic proper to each one of the cold phases which preceded them (in particular, the importance and location of mesophilous taxa refuges).

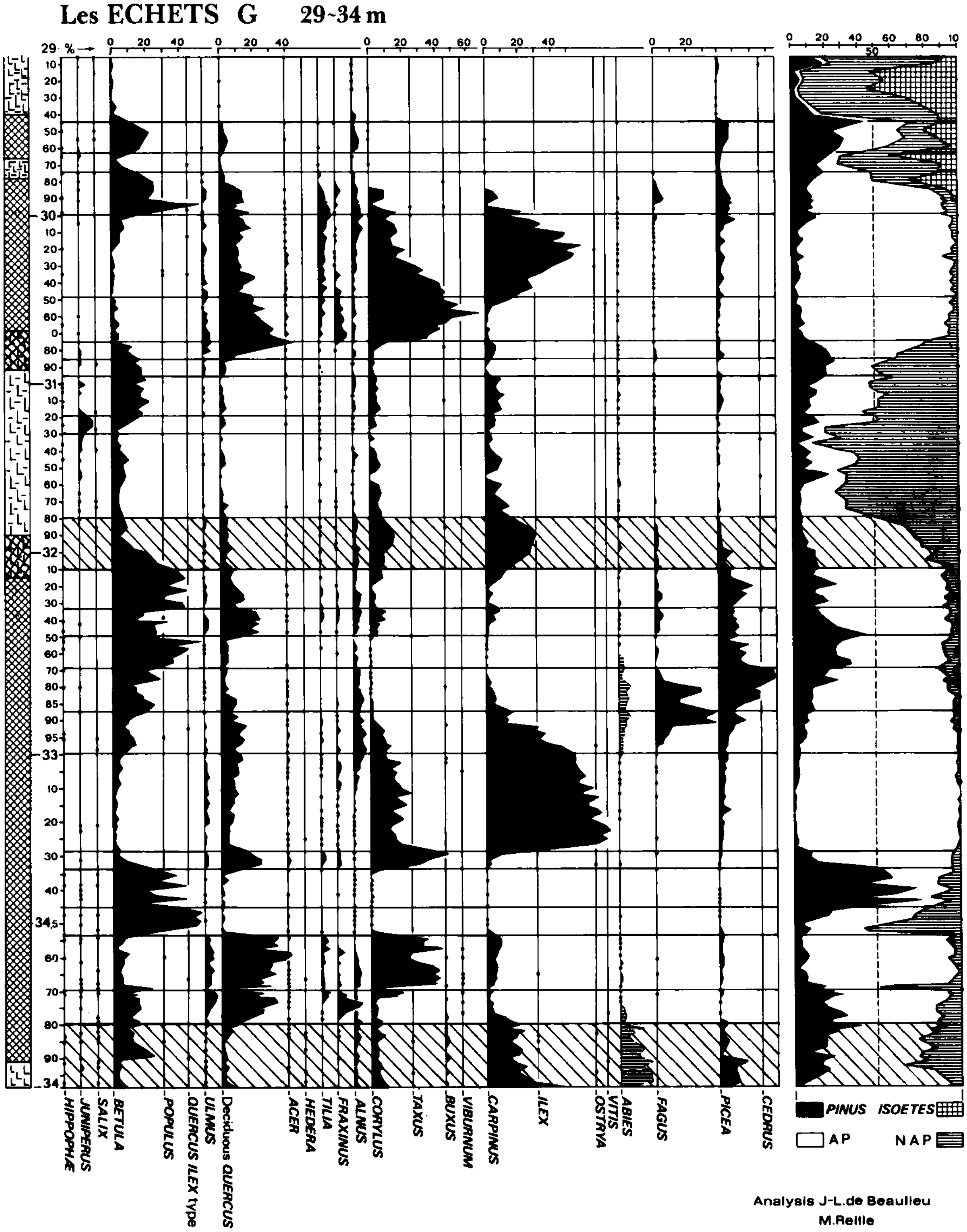
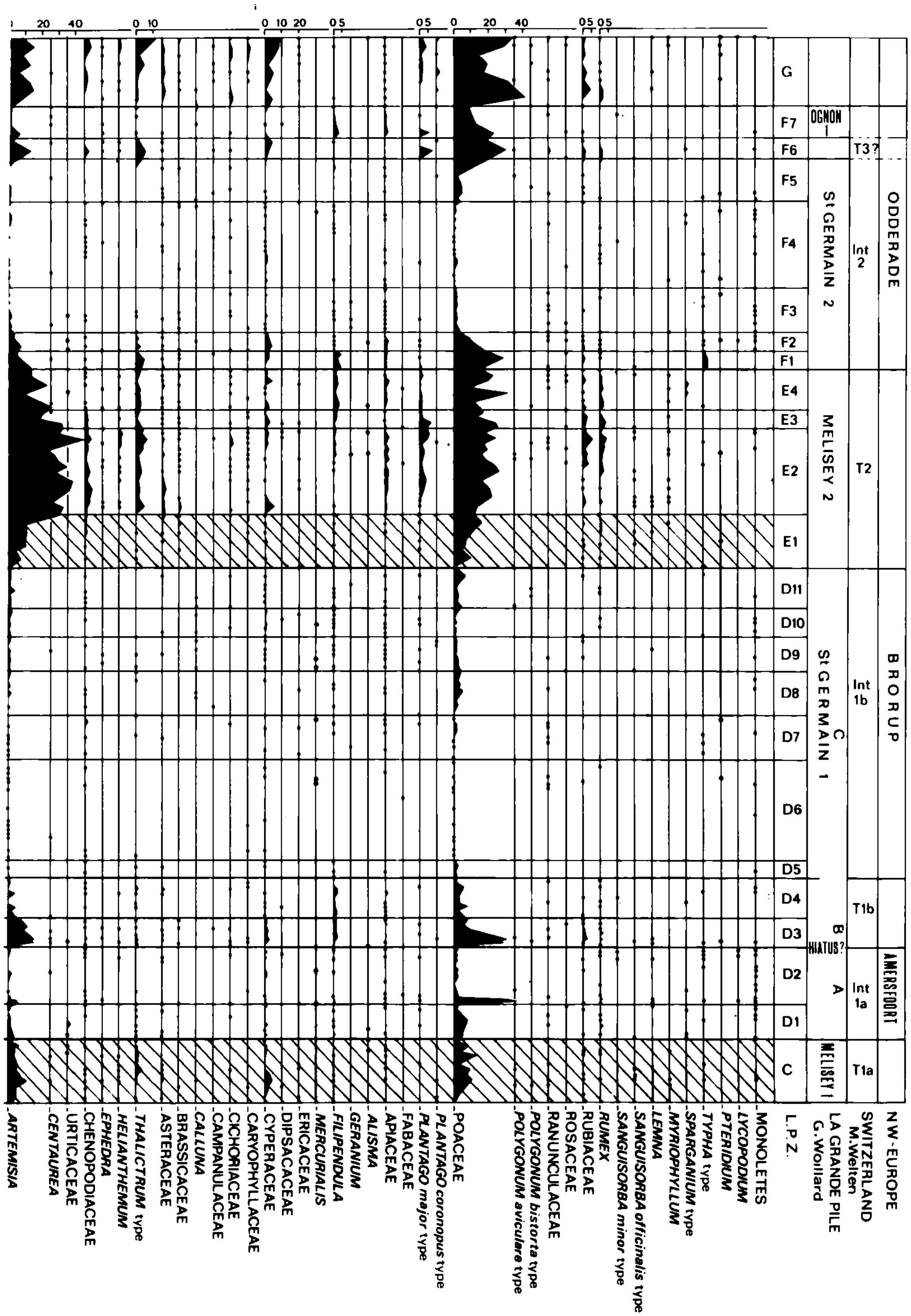


Fig. 3. Les Echets G: the lower middle part (29–34 m) of the pollen sequence.



ARTEMISIA
CENTAUREA
URTICACEAE
CHENOPODIACEAE
EPHEDRA
HELIANTHEMUM
THALICTRUM type
ASTERACEAE
BRASSICACEAE
CALLUNA
CAMPANULACEAE
CICHORIACEAE
CARYOPHYLLACEAE
CYPERACEAE
DIPSACACEAE
ERICACEAE
MERCURIALIS
FILIPENDULA
GERANIUM
ALISMA
APIACEAE
FABACEAE
PLANTAGO major type
PLANTAGO coronopus type
POACEAE
POLYGONUM aviculare type
POLYGONUM bistorta type
RANUNCULACEAE
ROSACEAE
RUBIACEAE
RUMEX
SANGUISORBA minor type
SANGUISORBA officinalis type
LEMNA
MYRIOPHYLLUM
SPARGANIUM type
TYPHA type
PTERIDIUM
LYCOPODIUM
MONOLETES
L.P.Z.
LA GRANDE PILE G.Woillard
SWITZERLAND M.Welten
NW-EUROPE
G
F7
F6
F5
F4
F3
F2
F1
E4
E3
E2
E1
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
C
OGNON I
St GERMAIN 2
MELISEY 2
St GERMAIN 1
MELISEY I
HIATUS?
T3?
Int 2
T2
Int 1b
T1b
Int 1a
T1a
ODDERADE
BRORUP
AMERSFOORT

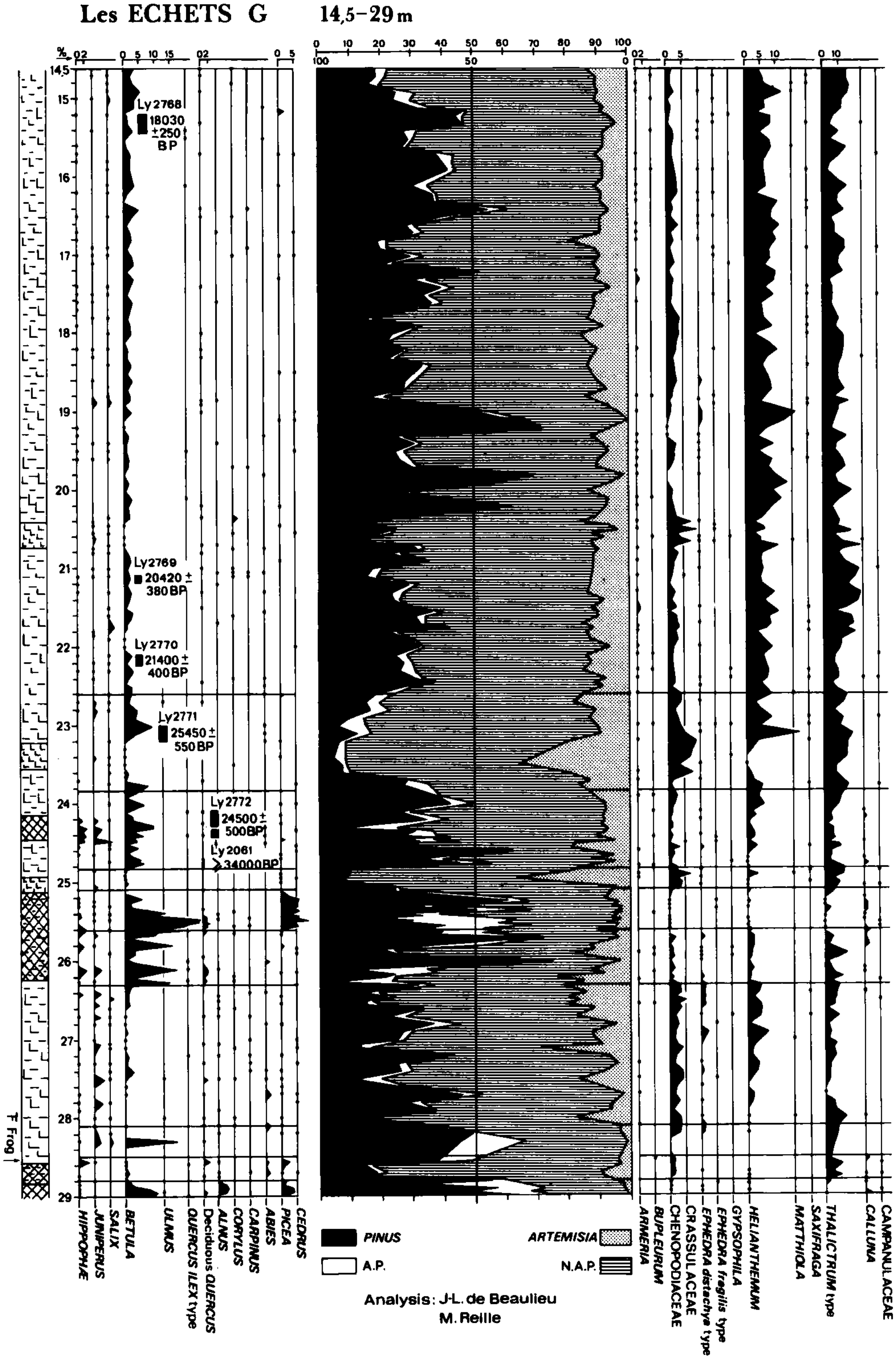
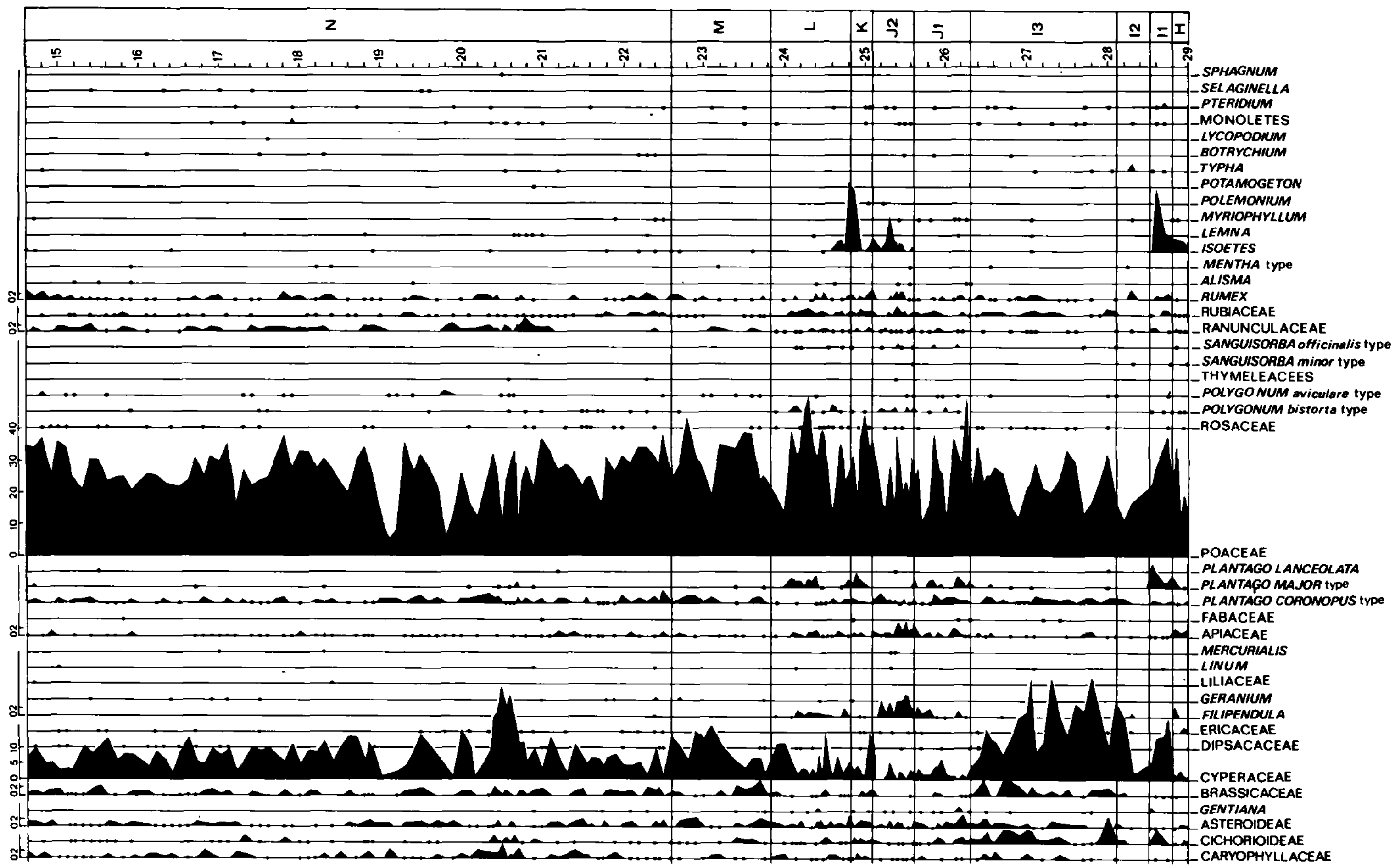


Fig. 4. Les Echets G: the upper middle part (14.5–29 m) of the pollen sequence.


N
M
L
K
J2
J1
I3
I2
I1
H
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
SPHAGNUM
SELAGINELLA
PTERIDIUM
MONOLETES
LYCOPODIUM
BOTRYCHIUM
TYPHA
POTAMOGETON
POLEMONIUM
MYRIOPHYLLUM
LEMNA
ISOETES
MENTHA type
ALISMA
RUMEX
RUBIACEAE
RANUNCULACEAE
SANGUISORBA officinalis type
SANGUISORBA minor type
THYMELEACEES
POLYGONUM aviculare type
POLYGONUM bistorta type
ROSACEAE
POACEAE
PLANTAGO LANCEOLATA
PLANTAGO MAJOR type
PLANTAGO CORONOPUS type
FABACEAE
APIACEAE
MERCURIALIS
LINUM
LILIACEAE
GERANIUM
FILIPENDULA
ERICACEAE
DIPSACACEAE
CYPERACEAE
BRASSICACEAE
GENTIANA
ASTEROIDEAE
CICHORIOIDEAE
CARYOPHYLLACEAE
0
10
20
30
40

D3. – The predominance of *Betula, Artemisia* and Poaceae indicates a climatic deterioration. The spectra from lower levels are the most typical of an arid and cold climate as well as of a sparsely wooded area. Besides, it is possible that the maximum of cold was reached during the preceding hiatus, so it is not recorded here.

D4. – The spectra suggest a boreal forest with *Pinus* and *Betula.* Steppe species are rare.

D5. – New dynamics of temperate forest are revealed with the expansion of *Quercus* followed by that of *Corylus* (the two steps, centred on 5 cm, have been united in a single zone for graphic convenience).

D6. – At the beginning of the zone, pollen percentages of *Carpinus* superior to 70% reflect the development of a thick woodstand. With the exception of *Carpinus, Corylus* is the only relatively abundant species; therefore it could maintain itself in the undergrowth and at the skirt of the forest. A.P. percentages exceed 97% (they sometimes reach 100%). Repeated occurrences of *Abies* and *Fagus* are to be ascribed to non-local populations.

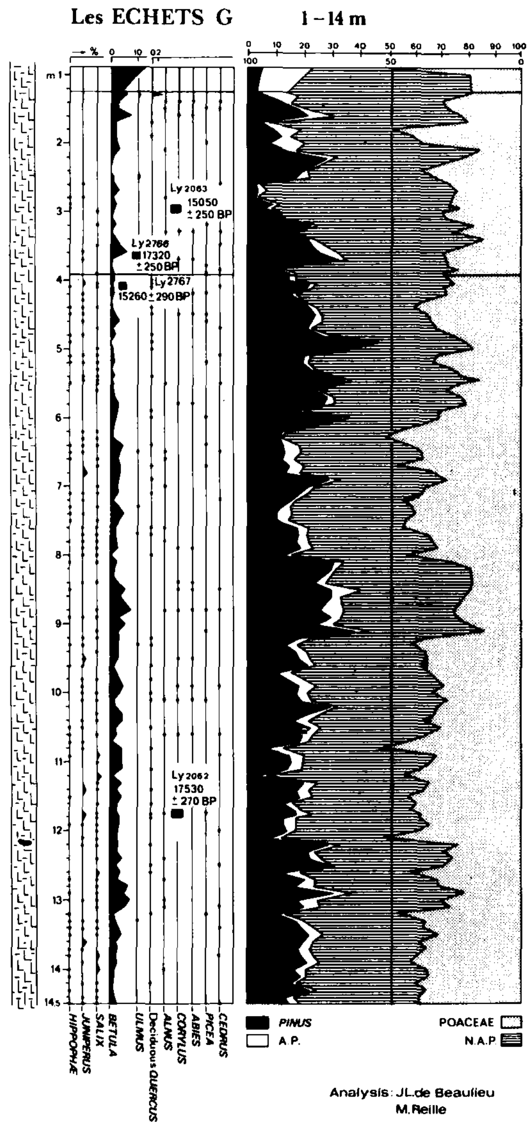
D7. – This is a regressive phase for *Carpinus.* The open character of *Carpinus* forest seems to have first favoured heliophytes: *Betula, Pinus,* even some steppe species which make a modest reappearance, and also *Picea, Alnus,* as well as *Abies* and *Fagus* whose curves are now continuous. At the end of the phase (D7b) *Fagus* percentages reach their maximum (40%), reflecting the presence of a beech grove (mixed with *Abies* and *Picea*) in the immediate surroundings of the lake.

D8-D9-D10-D11. – These zones correspond to a series of phases indicating a vegetational evolution toward a boreal forest: a decrease of *Fagus* mainly to the profit of *Picea* (D8), a phase with dominating *Betula* and *Pinus* (D9), an unexpected episode marked by a transitory increase in *Quercus* and *Corylus* values and probably due to a short positive climatic oscillation (D10), a phase with dominant *Betula* (D11).

Zone E

Zone E as a whole corresponds to a cold period.

E1. – The fall in A.P. frequencies is certainly largely masked by the rebedding of numerous allochthonous pollen grains of deciduous trees, so that botanically aberrant spectra are recorded, just as in C. This interpretation is confirmed by the composite nature of the sediment.



E2. – The mean percentages of A.P. are lower than 30%, though there still subsists a small quantity of rebedded arboreal pollen. The only local vegetation is a steppe with *Artemisia.*

E3 and E4 represent two successive 'Lateglacial' phases of weak extension for *Juniperus* and *Betula.*

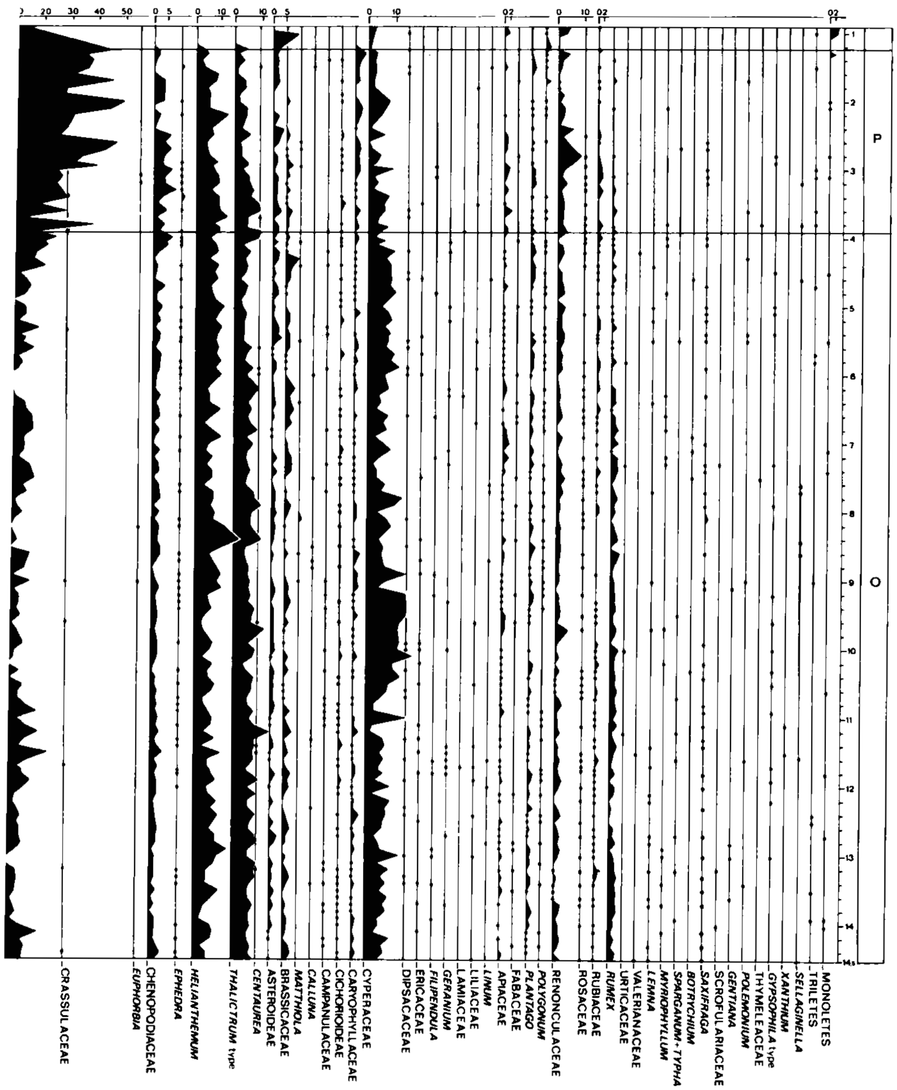


Fig. 5. Les Echets G: the uppermost part (1–14 m) of the pollen sequence.

Zone F

As a whole, zone F is an essentially temperate zone.

F1. – The temperate cycle starts with a phase characterized by a small maximum of *Pinus*.

F2. – As in D5, the expansion of *Quercus* constitutes a very transitory phase.

F3. – Shows *Corylus* optimum; *Quercus* is abundant and *Fraxinus* relatively well represented.

F4. – *Carpinus* forest is again flourishing (pollen percentages around 60%). *Tilia* reaches its maximum.

F5. – *Betula* rapidly becomes the dominant tree; most deciduous trees diminish or disappear. The pollen of *Picea* and *Pinus* slightly increases: it seems that climate deteriorates earlier and faster than in D. In spite of this rapid evolution after the *Carpinus* phase, *Fagus* seems to play a certain part in the regional vegetation with frequencies reaching 5%.

F6. – A.P. values strongly decrease owing to the abundant *Isoëtes* spores and to the great expansion of steppe species: a transitory aridity accelerates the climatic deterioration.

F7. – A last maximum of *Pinus, Betula* and, to a less degree, *Picea* indicates a return to the conditions that prevailed in F5, perhaps somewhat worsened.

Zones G to L

Zone G is characterized by a fall in A.P. values marking the beginning of a very cold period.

Zones H to L. – In Fig. 4, up to 23.90 m, these zones as a whole correspond to a cold complex. The most obvious character of this is the extreme irregularity of the curves, especially those of dominant taxa: *Pinus,* Poaceae, Cyperaceae, *Betula.* This general unsteadiness cannot be accounted for by the sudden variations in *Artemisia* and Cyperaceae frequencies, relatively low and steady in zones J and L, nor those of *Betula,* hardly present in zone I. It seems that this irregularity is essentially due to *Pinus,* perhaps also to Poaceae values.

This interpretation is confirmed by the relatively constant floristic composition of the spectra which excludes great changes in the vegetational structure. Therefore, the irregularity in the curves must be ascribed to sudden and repeated changes in pollen transport and deposition in the lake. Thus, the proposed zonation, even though attempting to take into account only the events considered as botanically significant, has but a punctual value.

Zone H, with frequencies of *Pinus* higher than 50%, of *Betula* lower than 10%, of *Alnus* and *Picea* lower than 5% and with rarefying steppe taxa, is undoubtedly an interstadial that locally indicates a sparse woodland.

Zone I corresponds to spectra characterized by the increasing abundance of steppe plants and a maximum of Cyperaceae. *Pinus* values ranging between 10 and 50%, rare *Betula* pollen and irregular *Juniperus* occurrences indicate woodless immediate surroundings and a sparse regional woodstand.

Zone J, corresponding to gyttja-silt levels, is marked by higher frequencies of *Pinus* and the reappearance of *Betula* with values around 25% near the site (J1) and of *Picea* with mean percentages of 5% in J2. About 26 m and 25.5 m, *Quercus* values regularly higher than 1% reflect an increase of the regional or distant transport from the Rhône valley, indicating a small extension of the tree around its refuges. Thus, zone J clearly indicates an interstadial.

In K, steppe species percentages notably increase, whereas those of *Pinus* are at their lowest: this is a very dry phase.

Zone L is centred around the last organic level of the series before the Holocene peat. *Picea* is almost absent, *Pinus* percentages oscillate around 35%. A single pollen grain of *Larix* is recorded. *Betula* is regularly present with low frequencies in a dy level, as well as *Juniperus* and *Hippophaë*; both species are present in the vicinity. The zone suggests a very weak interstadial.

Pollen zones G to L as a whole indicate a sparse vegetation under a cold and dry climate. However, taxa such as *Calluna, Filipendula, Sanguisorba officinalis,* and *Polygonum bistorta* type, regularly present during the interstadials H, J and L, suggest more or less differentiated short grass formations on wet soils from which could also come a part of the Apiaceae and *Plantago major* type pollen abundant during these periods.

In the Würmian Lateglacial of Middle Europe, these taxa generally appear at the end of the Oldest Dryas or later, and they can be considered as the first signs of the Lateglacial warming up (they require a mean July temperature superior or equal to 10 °C). Therefore it may be inferred that the climate that prevailed during the periods corresponding to zones G to L was much more temperate than at the beginning of the Oldest Dryas. It is possible that these taxa have colonized the shores of the lake and probably also numerous depressions on the Dombes plateau (*Betula* may have been associated with these taxa). Their juxtaposition in the pollen spectra with steppe species and with *Hippophaë* and *Juniperus* reflects the mosaic character of vegetation.

Zones M to P

Above 23.80 m prevail extremely arid conditions with high frequencies for steppe species and low frequencies for *Pinus*. This aridity, together with absolute dates, enables one to attribute zones N, O and P to the end of the Würmian Pleniglacial.

During this period, the long and continuous filling with more than 20 m of more or less silty clay is a typical feature of the sedimentary sequence of Les Echets. No new significant fact with regard to the already published diagram (Reille in Beaulieu *et al.* 1980) can be reported concerning the end of this Würmian Pleniglacial, for which 210 additional spectra have been recorded (so that this period is now represented at Les Echets with 316 pollen spectra). The striking regularity of the pollen curves points to a great stability in the vegetation; it is a cold and dry steppe with *Artemisia*, Poaceae, *Helianthemum, Thalictrum*, Chenopodiaceae, Cyperaceae and many other herbaceous taxa. Among the non-herbaceous plants that are likely to have existed in the immediate surroundings, *Hippophaë, Betula, Salix,* were certainly restricted to the humid border of the mire; *Juniperus* may have grown here and there. The presence of all the other pollen grains, except *Pinus,* is probably due to long-distance transport: this is the case in particular for *Quercus*, which occurs in more than a quarter of the spectra. As regards *Pinus*, whose frequencies always represent more than 80% of the total sum of trees, its curve reflects the following four zones: zone M with *Pinus* values of less than 10%, zone N with frequencies around 30% but with abrupt variations, zone O with values of 15 to 20% only, and zone P in which *Pinus* percentages fall to about 10, only the *Artemisia* curve shows such an abrupt variation with values becoming three times as high.

But, while long-lasting variations of mean *Pinus* percentages have been used to support this zonation, the more or less abrupt and short peaks of *Pinus* still have to be interpreted. Analysis of the three peaks in zone N shows that they reflect events of little value for a zonation.

As a matter of fact the first one (20.20 m), represented by a single spectrum, is a mere accident; in the other two peaks (19.8–19.9 m: two spectra; 19–19.2 m: three spectra), *Pinus* is the only tree concerned; as regards the herbaceous taxa, the main fact is the decreasing amount of *Artemisia,* Poaceae and Cyperaceae, whereas *Helianthemum* and *Thalictrum* have consistent or even higher frequencies. It is difficult to interpret these spectra. They may correspond either to a short minor biological event (formation of a sparse woodstand with rare *Pinus* in the region or the surrounding areas, or sudden and transitory increase in the pollen production of the few trees that still barely subsist nearby), or to local variations in the deposition process, as suggested by the hardly noticeable changes in the lamination of sediments.

As regards long-lasting variations in *Pinus* mean percentages at the base of the zonation, another interpretation must be put forward: in a widely open vegetation with long-distance pollen deposits of taxa as varied as *Quercus, Alnus, Ulmus, Abies, Picea* and *Cedrus, Pinus* pollen is much more favoured than the other types, as is shown by the study of modern pollen rain and atmospheric content in subdesert regions (Van Campo 1975). But, as pollen influx undoubtedly corresponding to long-distance transport (especially *Cedrus* and *Quercus*) does not vary between N and O, so must it be with *Pinus*. Therefore, the fall in *Pinus* frequencies between N and O cannot be interpreted but as an almost total disappearance of a previously existing regional tree cover which, anyway, must have been very sparse, as the indicators of the local herbaceous vegetation show unchanged values.

It should also be noted that in types of inorganic levels relatively poor in pollen, the validity of the spectra depends on the quality of their chemical treatment. Thus, out of nine pollen spectra recorded at Les Echets by Denèfle (in Billard & Denèfle 1981), one contains a single taxon, *Pinus,* and among the eight others, the floristically richest one contains only five herbaceous taxa (out of ten). Their bad treatment is probably accountable for the weakness of these spectra in which, in spite of the artificial abundance of *Pinus* pollen, *Artemisia, Helianthemum* and Chenopodiaceae frequencies indicate a Würmian age. None of the 316 spectra obtained at Les Echets for this period contains less than twenty taxa, and this number is frequently attained by the herbaceous taxa alone.

During this long sequence, the major botanical event occurs between O and P: it is the rise of *Artemisia,* Chenopodiaceae and Caryophyllaceae curves accompanied by an abrupt fall in *Pinus* values. Climatic conditions have therefore favoured the spread of a steppe with *Artemisia*, and the abundant pollen production of this taxon utterly conceals other manifestations of long-distance pollen transports. This fact confirms the interpretation that from the base of O the almost totality of *Pinus* pollen is due to long-distance transports. Among the trees, *Pinus* is not the only taxon whose frequencies suddenly fall; *Quercus* pollen, which is undoubtedly due to long-distance transport, disappears from the spectra. This phenomenon is precisely the reverse of what occurs at the boundary between M and N where the decrease in steppe species values causes an increase in the frequencies of *Pinus* pollen coming from long-distance transport. This great change between O and P takes place around 15,000 B.P. and marks the beginning of the Lateglacial, that is to say the transition from the end of the Würmian Pleniglacial to the Oldest Dryas (the date Ly 2766 17,320 ± 250 B.P. is of course cancelled by the two coherent dates that frame it).

The well-established and dated sequence of Les Echets does not give evidence of the least climatic amelioration of any length between 25,000 B.P. and the Lateglacial: none of the numerous interstadials that have been described and recognized in caves by non-botanist researchers and that encumber both the end of the Würm and the literature concerned can objectively be found; neither are they found in the diagrams from La Grande Pile published by Woillard (1975).

Profile G ends with a thick layer of reworked silt, sands and peat. Profiles from the centre of the bog show, above spectra very much similar to those recorded at the end of P, spectra characterized by more abundant *Juniperus* and aquatic species pollen dated from the Bölling times (Ly-2764: 12,190 ± 290, unpublished), and, after a large hiatus, a peat containing the Holocene vegetational history of the Dombes from Boreal times.

Comparisons with previous diagrams

As compared with preliminary borings, the pollen analyses of which have already been published (Beaulieu & Reille in Beaulieu *et al.* 1980), sequence G appears to be much more complete, as is shown in Table 1, which sums up the proposed stratigraphical equivalences. Recent diagrams confirm what was suggested by the nature of sediments (mainly sands and silt) and their pollen content in boring V; that is to say, on the borders of the mire the sedimentary process was not continuous, but was regularly broken by phases of erosion, deposits of reworked material from the drainage basin and probably also emergence phases. Because of these phenomena, interpretation of the preliminary diagrams was conjectural and detailed correlations with boring G are made difficult.

Inversely, the fact that boring V was nearer the shore of the lake explains, of course, occurrences of *Larix* pollen in several levels, whereas in G it has been found in a single level. However, there remain concordances between the two borings: the cold episode F6 was quite evident in diagram V, and as far as ^{14}C dates and pollen spectra are concerned, zone O corresponds to the sequence from the centre of the peat bog (Fig. 6).

Discussion

Comparison with other sequences: biostratigraphical equivalences

Though pollen sequences with a well-characterized Eemian have been described in numerous European sites, those where this period is overlaid with other temperate cycles are rare. One should mention on the one hand sites in Northern Europe: Odderade (Averdieck 1975), Oerel (Selle & Schneekloth 1965), Amersfoort (Zagwijn 1961), Brørup (Jessen & Milthers 1928; Andersen 1961), Kittliz (Erd 1973), Rederstall (Menke 1976), and on the other hand alpine deposits: Samerberg (Grüger 1979a), Dürnten and Sulzberg-Baden (Welten 1981, 1982), Mondsee (Klaus 1975).

Up to now, however, the only sequence starting with the Eemian and extending up to the Holocene without long interruptions is the sequence recorded at La Grande Pile, France (Woillard 1975, 1978). So, the comparison with diagrams from this site which, besides, is only 200 km from Les Echets, must be examined first.

La Grande Pile. – The differences existing in the pre-Eemian Lateglacial of the two sites appear to be partly due to a more rapid sedimentation at Les Echets. In both cases, the pioneer phase with *Juniperus* is a well-marked event.

As regards the Eemian, Table 2 sums up the correspondences between forest phases. The absence of an obvious *Taxus* phase at Les Echets may be explained by a hiatus at the boundary between zones B4 and B5, supported by a change in sedimentation. At La Grande Pile, *Taxus* maximum occurs just before the spread of *Carpinus,* already in good progress at the begin-

Table 1. Biostratigraphical equivalence between boring G and previous borings (Beaulieu *et al.* 1980).

CORRESPONDENCES BETWEEN POLLEN ZONES

BEAULIEU et al. 1980	Ia ?	absent	Ib	absent	IIa	IIb ?	absent	IIc1 reworking	IIc2	absent	IId	IIe
Boring G	A1	A2	B1	B2 B3	B4	B5	B6 B7 B8	absent	C	D1 D2 D3 D4	D5	D11

BEAULIEU et al. 1980	absent	IIf ?	IIg	III	IVa reworking	IVc	IVd	V	VI	VIIa	VIIbcd ?	VIIefg ?	VIIhij ?	Diag.II
Boring G	D7 D8 D9 D10	D11	E1	E2	absent	F4	F5	F6	F7	G	HIJ	KL	MN	OP

ning of B5. Increased *Abies* values reflect the more southern location of Les Echets and no doubt also the nearness of the Southern Alps which, during the Holocene (Beaulieu 1977) and during the preceding interglacials (Beaulieu 1981; Beaulieu & Monjuvent 1979), have been propitious to the development of the tree.

At Les Echets, zones B7, B8 and B9 show a double maximum of *Pinus* enclosing a second maximum of *Abies*. This points to a respite in the climatic deterioration at the end of the Eemian. This double maximum of *Pinus,* though less clearly marked, also appears in sequences III and X of La Grande Pile, but essentially to the benefit of *Picea.* Here also, differences in latitude may explain this different manifestation of a same climatic phenomenon, the first disappearance of *Abies* occurring earlier in the Vosges than in the Lyon region.

Above the Eemian and after a stadial phase, the correlation is easy between the two temperate cycles D and F and St-Germain I and St-Germain II. The division of St-Germain I in two temperate episodes separated by a cool phase characterized by a woodland with *Betula* and *Pinus* can also be recognized at Les Echets; in both sites, this cool episode, clearly evidenced in the diagrams, does not lead to notable changes in the lake sedimentation. The differences between the two sites (Table 3) are essentially related to higher percentages of deciduous trees at Les Echets and to the existence of a flourishing period for *Fagus* in D that is not present at St-Germain IIC. (However, it is precisely during the latter that repeated occurrences of *Fagus* pollen are recorded at La Grande Pile.)

At Les Echets, zones F6 and F7, which we consider as ultimate episodes of the last temperate cycle (before the Holocene), respectively correspond to the 'Eowürm stadial I' and to the interstadial 'Ognon I' of La Grande Pile X.

Table 2. The Eemian at Les Echets: a comparison with La Grande Pile.

Similarities with Grande Pile

1. Early *Ulmus* phase
2. *Quercus* phase preceding *Corylus* phase
3. Abundant *Buxus* (during *Carpinus* phase)
4. Well marked *Abies* phase
5. Presence of *Hedera* and *Ilex*
6. Scarcity of *Tilia*

Differences between Grande Pile and Echets

1. No *Taxus* phase (hiatus?)
2. *Abies* percentages twice as important
3. Two *Pinus* phases divided by a second maximum of Abies

Originalities

1. Some *Pistacia* pollen during *Corylus* phase
2. Modest presence of *Fagus* at the end of the Eemian

Above these last reference levels appear dominant cold phases. Correlations between the two sites are much more difficult here, especially as the series of numerous dates of boring XIX at La Grande Pile (Woillard & Mook 1982) refers to an unpublished diagram, whereas between G and M our pollen diagram is not supported by any reliable date. It is probable that zones G to M correspond to the end of Lanterne I and to Lanterne II of La Grande Pile, and that zones N, O and P represent, as Lanterne III, the end of the Pleniwürm.

At Les Echets, between G and M, only three interstadials can be distinguished, whereas six are described by Woillard (1979) at La Grande Pile in the corresponding interval. As a matter of fact, the miscellaneous and varying content of the pollen spectra from Ognon II and Ognon III explains the hypothesis proposed by Grüger

Table 3. Compared sedimentation and pollen frequencies at Les Echets and at La Grande Pile during the post-Eemian temperate cycles.

Phase		Les Echets G		Grande Pile X		Post-Eemian cycle
			Thickness			
% Maximum	Carpinus	55%			18%	
	Corylus	60%	1.25 m	80 cm	40%	St-Germain II
	Quercus	40%			40%	
			90 cm	50 cm		Melisey II
Phase with	Fagus	present			absent	
% maximum	Carpinus	75%			35%	
	Corylus	45%	1.30 m	1.20 m	28%	St-Germain IC
	Quercus	25%			25%	
Phase with	Carpinus	absent			present	
High NAP % phase		present(??)	30 cm	40 cm	absent	St-Germain IA
% max. Corylus + Quercus		65%			30%	

(1979b) that they include quite a number of rebedded pollen, which deprives them of all botanical, and thereby climatical, significance. Besides, it is regrettable that for La Grande Pile no proper biostratigraphical synthesis has been made which could provide a general interpretation taking into account, for each period, all the pollen data of all and each profile where the period is represented. It would surely have prevented many weaknesses, and in particular the one that has just been referred to.

Of course, the Les Echets sequence may also contain hiatuses accountable for the absence of interstadial episodes in levels between G and M. But it should be noted that during climatically not well-characterized periods – that Welten (1981) refers to as 'interphases' – there must have existed gradients establishing local thresholds favourable to the transitory and short expansion of arboreal vegetation types whose development was mostly dependent on the situation and importance of refuges inherited from a regional past.

So, the point is not to explain the fact that six interstadials were recognized at La Grande Pile, whereas only three are found at Les Echets: it is probable that in both sites these episodes cannot be used as biostratigraphical references, as during the period considered, the local character of the vegetation may have been very different from one site to the other.

For Lanterne II and zones N-O-P, ^{14}C datings are a support to correlations because the two lakes had a different evolution: sedimentation was still very slow at La Grande Pile, while the filling of Les Echets depression was progressing more rapidly (about 3 m in a millenary); this phenomenon is no doubt related to eolian transports, as is shown by the abundant Würmian loess deposits in the near Rhône Valley. The 'Marcoudan' interstadials at La Grande Pile essentially correspond to variations in the aquatic flora; they do not show significant changes in the regional vegetation, so La Grande Pile diagrams do not contradict those of Les Echets; the absence of any indication of a climatic oscillation in the latter shows that there occurred no far-reaching change during the end of the Würmian Pleniglacial.

Other sequences from Middle European regions. – As Les Echets perfectly correlate with La Grande Pile, it is possible to use the comparisons made by numerous authors between this site and other European sites, and in particular the detailed analyses by Grüger (1979a) and Welten (1982). In Northern Germany, in Holland and in Denmark, the episodes immediately following the Eemian (Amersfoort, Brørup and Odderade) are at best characterized by a sparse woodland pointing to a rather hard climate, much unlike what is suggested by deciduous forests at St-Germain I and St-Germain II. In the Bavarian Alps and in Switzerland phases with a thick *Picea* woodstand have been described.

For some authors, these differences reflect an asynchronism between various vegetational cycles. Then, as has been suggested by Woillard (1975), the episodes with sparse woodstands after St-Germain II at La Grande Pile (Ognon II and Ognon III) might correspond to the Amersfoort, Brørup and Odderade interstadials of these reference sites. This opinion agrees with Frenzel's hypothesis (1973, 1976, 1980): on the basis of geomorphological and palynological data from Southern Germany, most of them unpublished, the author maintains the theory that the Eemian and the Riss-Würm are two different interglacials; in which case, one of the St-Germain episodes might correspond to the Alpine Riss-Würm.

For most palynologists, the vegetational differences observed from NW to SE reflect climatic gradients and do not exclude a synchronism between vegetation types of St-Germain and Brørup or Odderade. This point of view is adopted by Welten (1982), West (1982) and Grüger (1979a and b), who rightly pointed out on the one hand the insufficient data on which the interstadials Ognon II and III are based, and, on the other hand, the unexplainable absence of equivalents for the episodes St-Germain I and St-Germain II in numerous sequences from Western Europe if one refers to Frenzel's hypothesis.

A third interpretation, based on palaeomagnetic comparisons beyond our competence, is proposed by Mörner (1979). Notwithstanding the identity of the Eemian and the Riss-Würm, the author believes that St-Germain II corresponds to Brørup and that St-Germain I is a new interstadial (with no equivalent in Northern Europe). From the biostratigraphic point of view this hypothesis meets the same difficulties as those proposed by Woillard (1975).

So, we adopt the second theory that places St-Germain episodes in the Early Würm, because pollen analyses at Les Echets provide the following arguments in favour of it:

(1) The great similitudes in the vegetational history at Les Echets and La Grande Pile imply biostratigraphic correspondence in spite of differences due to historical (refuges) or topographic particularities proper to each site.

If such differences exist between sites so close to each other and almost at the same altitude, no wonder they increase in more northern and eastern sites. Thus, for the three Early Würmian temperate phases, one may conceive the following distribution of vegetation: a southwestern area characterized by the extension of mesophytic deciduous trees, an alpine one essentially marked by the flourishing of *Picea* (a phenomenon that shows the very early success of the genus to the east of the Alps during the Postglacial), lastly a north-European area, mainly characterized by *Pinus* and *Betula* expansion, with low amounts of *Picea* and *Larix* (except for the Dutch 'Brørup' where *Picea* frequencies may attain 47%). The existence of intermediate conditions confirms this representation: thus, at Sulzberg Baden, Switzerland (Welten 1982), in spite of the dominance of *Picea*, phases are described during which chiefly *Corylus*, but also some elements of the oak forest know a short success that does not appear at Samerberg, Bavaria (Grüger 1979b).

The hypothesis that during the forest optima of zones D and F Les Echets were lying on the eastern border of the mesophillous forest area is also confirmed by pollen analyses made in lignites at Val du Bourget (Savoie) by Gremmen (1982). Though pollen sequences are discontinuous, so that the correlations proposed by the author are rather conjectural, most of the lignites can undoubtedly be attributed to the interstadials of the Early Würm. Compared with the temperate cycles at Les Echets, there are at Val du Bourget (at the same altitude but in a more mountainous environment), phases with less deciduous trees but more *Pinus* and mostly *Picea*; these particularities indicate a narrowing of the vegetation stages as compared with present and Eemian conditions.

(2) On the other hand, and reversely, above zones D and F of Les Echets, no pollen spectrum in the region now exhibits an arboreal vegetation as well characterized as that which is found during the Brørup and even the Odderade interstadial in Holland and Northern Germany. Therefore, there only remains the alternative between the equivalences proposed here and the not very obvious presence of long hiatuses at Les Echets and even La Grande Pile.

It should also be mentioned that in the long pre-alpine sequence, the same difficulties arise – though under different aspects – as those that have been discussed concerning correlations between interstadials F7, H and J at Les Echets and the interstadials posterior to St-Germain II at La Grande Pile. Thus, even though *Larix* reached Les Echets at the end of cycle F, for this genus no trace is found of an expansion phase such as that which, in Switzerland, characterizes (Welten 1981) the interstadial 'FW3' or 'Dürnten interstadial'; therefore, the latter may as well correspond to F7 as to H.

(3) As pointed out by Woillard (1975), the three temperate cycles of St-Germain (Ia, Ic and II) show interglacial characteristics; so also do zones D and F at Les Echets. Yet they do not exhibit an optimum as hot as the Eemian. In fact, at Les Echets, in some Eemian levels, the abundance of *Hedera*, the presence of numerous pollen grains of *Ilex* and of a few of *Viscum* and *Vitis* suggests favourable climatic parameters (cf. Iversen 1944) similar to those of the Boreal or Atlantic optimum (during which *Vitis* and *Hedera* are frequently recorded). On the contrary, in zones D and F, only two pollen grains of *Hedera* and a single grain of *Vitis* and of *Ilex* have been found but none of *Viscum* and *Pistacia*. It is therefore likely that Les Echets and La Grande Pile were then in a climatic zone propitious to the development of deciduous trees near the northern boundary of *Hedera* and *Viscum*, which nowadays corresponds to Denmark or southern Scandinavia. As far as temperatures are concerned, this indicates mean monthly temperatures at most inferior to 3°C for January and to 6°C for July compared with those recorded at Les Echets today.

The chronostratigraphic problem

During the post-Eemian temperate cycles, and more markedly at Les Echets than at La Grande Pile, vegetation goes through very different successive forest phases that suggest immigration, maturation and competition processes, all of them of long duration. Moreover, information cautiously derived from sedimentation points to the following facts: in a forest environment presumably as dense as that of the Eemian, organic sediments deposited during cycles D and F are much like the Eemian ones; similar sedimentation rates can therefore be inferred. They are nearly as thick (1.60 m in D, 1.25 m in F) as in the Eemian (2 m), so one may attribute to cycles D and F a duration slightly shorter than ten millenaries.

Only the relative duration of stadial phases C and E can be assessed. The first is characterized by silt deposits with abundant rebedded pollen from the Eemian, whereas the second starts with levels containing a great amount of rebedded pollen followed by levels with an almost pure cold microflora; this suggests for soils and deposits an erosion phase dating from cycle D followed by a stabilization phase in a steppe environment. Moreover, silt layers are thicker in E than in C; this difference is even more obvious at Samerberg (Grüger 1979b) between the two equivalent cold phases (Z13: 45 cm, Z20: more than 2 m).

These facts lead us to attribute a longer duration to stadial E. Welten (1982), however, expresses the opposite view as regards Switzerland, where he stresses the great importance of the glacier advance T1 equivalent to stadial C.

However that may be, zones D, E and F as a whole certainly represent a longer period than the 15,000 years ascribed to the Early Würm (between 55,000 and 70,000 B.P.) on the basis of ^{14}C dates from various continental origins. Moreover, the recently published datings of La Grande Pile (Woillard & Mook 1982) yielded for St-Germain II an age older than 70,000 years. The authors conclude: 'several investigators would like to see the Early Weichselian interstadials Amersfoort, Brørup, and Odderade as matching Grande Pile pollen zones 4, 6, and 8, respectively, locally named St. Germain I (zones 4 through 6) and St. Germain II (zone 8). This possibility appears, however, to be in conflict with the old date inferred for the top of zone 8', thus justifying their hypothesis that the equivalents of Amersfoort, Brørup and Odderade at La Grande Pile are Ognon I, Ognon II and Ognon III.

Consequently our hypothesis implies that either La Grande Pile dates be rejected or those concerning North-European stratotypes on which the generally admitted duration of the Early Würm is based. We adopt the second solution for the following reasons:

(1) The close correlation established by Woillard (1978) between the La Grande Pile sequence and the North-Atlantic marine stratigraphy (Shackleton 1977) is confirmed by the dates obtained for La Grande Pile (Woillard & Mook 1982).

(2) For times before 30,000–40,000 B.P., ^{14}C datings are of little significance. The promises expected from the development of the enrichment method in radiocarbon dating (Grootes 1977) are vanishing in view of the results obtained, and one must admit that the ages provided are *minimum ages*, as has been pointed out by Mangerud (1981): 'Radiocarbon dating, when yielding finite or infinite ages below ca 20,000, provides an unambiguous minimum age'.

Numerous incoherences in dates series explain these reserves:

– Welten (1977), not without optimism, writes

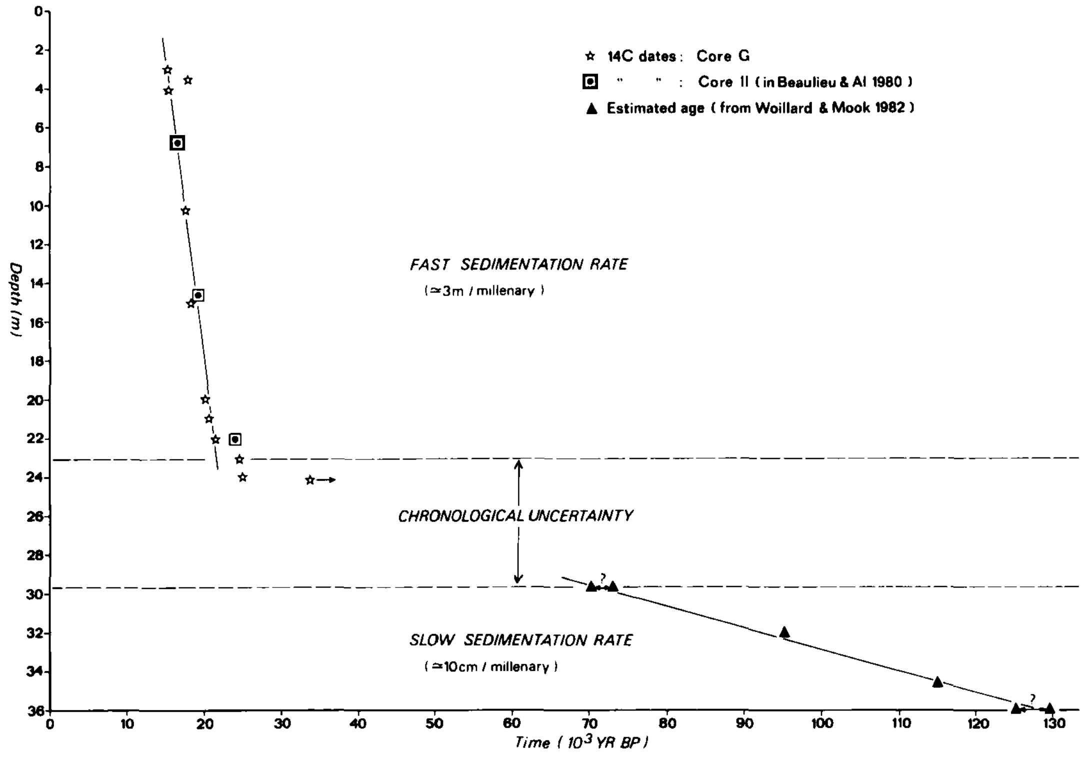


Fig. 6. Chronology and sedimentation rate at Les Echets.

concerning the lignites of Ambitzgi, Switzerland: 'Die zahlreichen Messungen an Ober- und Unterseiten und aus der Mitte von dicken Schieferkohleschichten und solche an dünnen Schieferkohleschichtchen geben so ungleiche, und schwankende Alter, dass nur die grossen Züge der Alterbestimmung wiedergegeben werden können.'

– At Odderade (Averdieck 1967), the two dates obtained for the Brørup interstadial (54,500 and 51,100) are younger than those of the Odderade interstadial (58,500 and 56,700).

– At Le Villard (France), a finite age of ca. 54,200 B.P. $\frac{+1{,}800}{-1{,}500}$ was yielded for *Pinus silvestris* trunks found at the bottom of a sequence in which *Abies* frequencies do not allow an age younger than the Brørup (Beaulieu 1981).

– In the Le Bourget region (France), the dates of lignite sequences studied by Gremmen (1982) prompt the following comments by the author: 'Not all the radiocarbon dates obtained for the lignites from the Grenoble area (Table 2) can be brought in line with the chronostratigraphy based upon geological and palynological evidence'.

All these facts show that the ^{14}C chronology of the Early Würm is still very unreliable and even dangerous because the general practice that tends to credit the dates that most closely adjust to a 'classical' schema and leads to reinforce the latter by virtue of a 'reinforcement syndrome' (Watkins 1971) has nothing to do with a scientific approach.

(3) The first results of Ionium dating in peat (Vogel 1982) show from the present up to ca. 15,000 B.P. a good agreement with ^{14}C dating. For more ancient times they generally yield ages older than ^{14}C ages but quite consistent with the marine chronology. The end of the Eemian is dated 115,000; thus, the first Ionium dates for Savoy lignites by Vogel in Gremmen (1982) are on average about 20,000 years older than those provided by enriched radiocarbon measurements.

But between the Early Würm, the end of

which has just been dated at 70,000 B.P., and the Late Würm, to which must probably be ascribed the part of the Echets sequence above the base of zone N – dated at ca. 25,000 B.P. – there extends a long and complex period to which belong zones G to M. A particular difficulty arises because two datings of dy in zone L have yielded two incompatible results: 'older than 34,000 B.P.' and '24,500 ± 500 B.P.'. To admit the second date means placing the beginning of the rapid sedimentation rate of the Late Pleniglacial at the latest at the beginning of zone L. To credit the first date infers that this sedimentation rate has prevailed only from zone N onwards. In the first case, interstadial L could correspond to interstadial D of La Grande Pile, the last one before the Late Pleniwürm, whose botanical characters, besides, are not more strongly marked (Woillard & Mook 1982). The entirely clayey zone K would then represent a stadial episode the duration of which is probably longer than is suggested by the thinness of the zone. In the second case, zone M, also mostly argillaceous, would result from a long and particularly slow sedimentation process.

But the real difficulty in interpreteting zones G to M lies in the fact that they are situated at the turning point between a long period with a very slow sedimentation rate (zones B to G) and a period with a very rapid sedimentation rate (zones N, O and P) (Fig. 6), so it is difficult to locate the change from one rate to the other or to evidence an alternation of both rates.

Therefore it would be of greatest interest to study, at Les Echets, several sequences easily recognizable between St-Germain II Interstadial on the one hand and levels that can be well dated through radiocarbon on the other hand, and to have them dated using several methods. Such sequences are found in a very few sites only, and, moreover, Les Echets sequences would *a priori* offer the advantage of permitting reliable correlations with La Grande Pile.

Conclusions

The pollen sequence of boring G in Les Echets ancient lake covers the end of the penultimate glacial cycle and the whole Upper Pleistocene times. It shows striking similarities with La Grande Pile: after the Eemian, two great temperate cycles D and F comprise densely forested phases with mesophytic deciduous trees, in particular *Carpinus*; the oldest of these cycles includes two climatic optima divided by a short climatic deterioration favourable to a boreal forest with *Pinus* and *Betula*.

The vegetation, which during all the temperate phases reflects a climate slightly warmer than at La Grande Pile, the existence of a phase with *Fagus* during cycle D and other slight differences between the two sites are explained by differences in the latitude and location of the sites with respect to refuges during cold periods.

The end of the Eemian, as well as that of phases D and F, is marked by climatic oscillations excluding the hypothesis of a sudden and catastrophic end for temperate cycles. During the post-Eemian temperate cycles, the climatic optima were markedly less warm than during this interglacial, and we correlate them to the Amersfoort, Brørup and Odderade interstadials of the Early Würm in Northern Europe; however, we admit the absolute chronology proposed for La Grande Pile that dates the end of these interstadials at ca. 70,000 B.P. On the basis of datings made by Vogel (1982) for the end of the Eemian, we suggest for the Early Würm an age between 115,000 and 70,000 B.P.

In spite of the difficulties in characterizing the Middle Würm, three periods with a sparse tree-cover are considered as short and not yet dated interstadials. *Picea* is present in the first two, but absent from the third. During the late Würm prevail the coldest and most arid conditions; no interstadial episode can be distinguished. The increase in *Artemisia* values toward 15,000 B.P. marks the transition from the Pleniglacial to the Oldest Dryas.

No other Upper Pleistocene sequence as complete as that of Les Echets has been known up to now in Middle Europe, except at La Grande Pile. The two sequences support each other and can easily be correlated to deep-sea sequences. Therefore, Les Echets – where some stratigraphic details require further borings – and La Grande Pile should henceforth be considered as the best Middle European stratotypes likely to give a new frame to the now available information concerning the Pleistocene.

The existence of long periods that are climatic intermediates between interglacials and stadials, such as have been evidenced for the Early Würm, opens a wide field for a new global climatic 'problématique'; one not yet approached with the general climate models established for past well-studied periods (maximal glacial cold: Climate Project and Programme National d'E-

tude de La Dynamique du Climat) and for Holocene interglacial times.

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