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Jacques-Louis de Beaulieu et Maurice Reille

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THE POLLEN SEQUENCE OF LES ÉCHETS (FRANCE): A NEW ELEMENT FOR THE CHRONOLOGY OF THE UPPER PLEISTOCENE

Jacques-Louis de BEAULIEU and Maurice REILLE, Laboratoire de botanique historique et palynologie, ERA CNRS n° 404, Faculté des sciences et techniques Saint-Jérôme, université d'Aix-Marseille, 13397 Marseille cedex 13, France.

ABSTRACT Les Échets mire (near Lyon, France) is one of the very few European sites showing an almost continuous record from the glaciation that preceded the Eemian up to now. The pollen diagram can easily be correlated with those from Grande Pile (Vosges). On the basis of a comparison between the two sequences, the age of three clearly temperate post-Eemian episodes (Saint-Germain Ia, Ic and II at Grande Pile) is discussed. The authors correlate these episodes with the Early Würm Interstadials of Amersfoort, Brørup and Odderade described in Northern Europe and accept the chronology of Grande Pile that dates Saint-Germain I and Saint-Germain II between ca 115 000 and 70 000 BP, thus making them equivalents of deep sea isotopic stages 5c and 5a. This leads to refute the ¹⁴C chronology admitted up to now that places the Early Würm between 75 000 and 55 000 BP. Considering the predominant temperate episodes during this period, the authors propose to use the term "Pre-Würm" instead of "Early Würm". During the Middle Würm, three not well-marked interstadials can be recognized. No interstadial is found during the late Pleni-Würm.

RÉSUMÉ La séquence pollinique des Échets (France): une nouvelle donnée pour la chronologie du Pléistocène supérieur. Le marais des Échets (près de Lyon, France) constitue l'un des rares sites européens qui présente un remplissage à peu près continu depuis la glaciation qui a précédé l'Éémien jusqu'à nos jours. Le diagramme pollinique peut aisément être mis en corrélation avec ceux de La Grande Pile (Vosges). À partir de comparaisons entre ces deux séquences, la position chronostratigraphique des trois épisodes très nettement tempérés post-éémiens (Saint-Germain Ia, Ic et II à La Grande Pile) est discutée. Les auteurs mettent en corrélation ces épisodes avec les interstades du Würm ancien, Amersfoort, Brørup et Odderade, décrits en Europe du Nord et acceptent la chronologie de La Grande Pile qui situe Saint-Germain I et II entre environ 115 000 et 70 000 BP et qui en font les équivalents des étages isotopiques océaniques 5c et 5a. Ceci implique que la chronologie ¹⁴C admise jusqu'ici et plaçant le Würm ancien entre environ 75 000 et 55 000 BP est totalement erronée. Compte tenu de la prépondérance des épisodes tempérés durant cette période, les auteurs proposent le remplacement de la dénomination "Würm ancien" par celle de "Pré-Würm". Durant le Würm moyen, trois interstades de faible amplitude ont été reconnus aux Échets, alors qu'aucune variation climatique positive n'est décelable durant le Pléni-Würm final.

ZUSAMMENFASSUNG Pollen Sequenz von Les Échets, Frankreich: Ein neues Element für die Chronologie des oberen Pleistozän. Das Moor von Les Échets (in der Nähe von Lyon, Frankreich) ist eines der wenigen europäischen Gelände, das ein fast kontinuierliches Zeugnis ablegt von der dem Eemian vorausgehenden Eiszeit bis heute. Das Pollendiagramm kann sehr leicht mit denen von Grande Pile (Vogesen) in Zusammenhang gebracht werden. Ausgehend von dem Vergleich zwischen diesen zwei Sequenzen wird das Alter von drei auf das Eemian folgenden und eindeutig gemäßigten Stadien diskutiert (Saint-Germain Ia, Ic und II in Grande Pile). Die Autoren setzen diese Episoden in Beziehung zu den Interstadialen von Amersfoort, Brørup und Odderade, die in Nord Europa beschrieben werden und akzeptieren die Chronologie von Grande Pile, die Saint-Germain I und Saint-Germain II zwischen etwa 115 000 und 70 000 v.u.Z. datiert, und sie so zu Äquivalenten der isotopischen Tiefsee-Stadien 5c und 5a macht. Das führt zu einer Ablehnung der ¹⁴C Chronologie, die bisher galt, und das frühe Würm zwischen 75 000 und 55 000 v.u.Z. ansetzte. Unter Beachtung der dominierenden gemäßigten Episoden während dieser Zeit schlagen die Autoren vor, den Terminus "Prä-Würm" an Stelle von "Frühes Würm" zu benutzen. Während des Mittel-Würms können drei nicht gut voneinander abgegrenzte Interstadiale erkannt werden. Während des späteren Pleni-Würms kann kein Interstadial festgestellt werden.

INTRODUCTION

In the 1970's there was consensus on the main divisions of the Upper Pleistocene in Europe: after the Eemian interglacial, the Early Würm (Between ca 70 000 and 55 000 BP) was characterized by an alternation of cold periods and three interstadials [Amersfoort (ZAGWIJN, 1961); Brørup (ANDERSEN, 1961); Odderade (AVERDIECK, 1967)] marked in stratotypes by a sparse woodland with *Betula*, *Pinus*, *Picea* (in particular *Picea omorikoides*); the Würm Pleniglacial was marked by much colder climatic conditions, relatively humid at first, then more arid; the Stiefried B Interstadial (FINK, 1956) around 30 000 – 35 000 BP was the only clear warming.

In 1975 and 1978, G. WOILLARD published pollen analyses from Grande Pile, the only West-European lacustrine sequence showing a continuous record since the glaciation that preceded the Eemian. These analyses showed two "Interglacials" after the Eemian: Saint-Germain I and Saint-Germain II, characterized by phases of forest development of deciduous trees, in particular *Carpinus*; the first interglacial was divided by a median cold phase (Saint-Germain Ib) with a boreal *Pinus* and *Betula* forest.

Following B. FRENZEL's concepts (1973, 1976, 1980) according to which the North-European Eemian is anterior to the Alpine Riss glaciation, and therefore to the Riss-Würm Interglacial, Woillard put forward the hypothesis that Saint-Germain I and II represent events not yet described and correspond to an interval between the Eemian and the Early Würm which probably also includes the Riss-Würm.

However, a second interpretation, that the interglacials Saint-Germain Ia, Saint-Germain Ic and Saint-Germain II are the southern equivalents of the Amersfoort, Brørup and Odderade interstadials led to an exchange of opinions in the literature (GRÜGER, 1979a, WOILLARD, 1979, BOWEN, 1979, MANGERUD *et al.* 1979). Evidence from the Alps for the existence during the Early Würm of forest stages intermediate between those of Grande Pile and northern Europe (GRÜGER, 1979b; WELTEN, 1982) provided support for the second interpretation. On the other hand, the recent publication of ¹⁴C dates from Grande Pile placing Saint-Germain II older than 70 000 yr BP supports the first hypothesis (WOILLARD and MOOK 1982).

Our pollen data from Les Échets (BEAULIEU *et al.*, 1980) bring new evidence to bear on the controversy. This site resembles Grande Pile in that it provides an almost continuous sedimentary record for the Upper Pleistocene. It is located north-east of Lyon on the Pliocene Dombes Plateau, in a zone that was covered by the Rhone Riss glacier (BORLAND *et al.* 1976) but was ice-free during the entire Würm. It lies 200 km south of Grande Pile (Fig. 1).

The upper 39 m of sediment from a 56 m boring yielded pollen, and detailed analysis of more than 740 levels will be reported elsewhere (BEAULIEU and REILLE, 1984). A summary pollen diagram based on 168 sample levels shows only the main taxa (Fig.2). A variable depth scale is used to accommodate all the pollen zones. It intends to reflect in a minimum of space all the pollen zones evidenced; that is why the depth scale is not always the same. In fact, some very

thin sections contain a great number of events, whereas other thicker sections (especially in the upper part) show more homogeneous pollen spectra.

THE LOCAL VEGETATIONAL HISTORY

The diagram is divided into zones (letters) which correspond to the main climatic events, and subdivided in sub-zones which are local pollen zones (numbers).

ZONE A represents the end of glacial period with a vegetation essentially dominated by herbaceous — especially steppic — formations; A2 reflects a late glacial period marked by increases of *Juniperus* and *Betula*.

Zone A is overlain by three layers of black organic mud (gyttja) divided by silt beds; they are characterized by forest cycles all of them including a phase with *Carpinus* (zones B, D and F).

ZONE B partly corresponds to the lowest gyttja layer; the important role of *Abies* and the presence of *Hedera*, *Buxus* and *Taxus* indicate the Eemian.

ZONE C presents pollen spectra including a high percentage both of N.A.P., especially steppe species, and of mesophilous trees (*Carpinus* and *Abies*). It is very unlikely that a natural vegetation could yield such a pollen assemblage. Considering that the thermophilous pollen grains lie in silty layers with rebedded gyttja fragments from underlying levels, they certainly come from the preceding interglacial. If one excluded these taxa, the herbaceous percentages would at least be doubled, which suggests a very cold phase.

ZONE D, which corresponds to the median gyttja layers, includes: **a**) a first anathermic phase marked by the expansion of *Quercus* followed by *Corylus* (divided by a short episode with spectra containing abundant N.A.P., especially Poaceae; it is certainly an accidental event, as it does not prevent a *Corylus* expansion); **b**) a regression phase with an open boreal forest (D3, D4); **c**) lastly, a new cycle (D5 to D11) of temperate forests. It is marked by a flourishing of *Carpinus* as clear as during the Eemian and by an expansion phase of *Fagus*.

ZONE E, corresponding to silts shows the characteristics of a cold climate with an initial phase marked by deep reworkings (E1) and two "late glacial" phases with *Juniperus* (E3) and *Betula* (E4).

ZONE F (uppermost gyttja level) also shows a temperate forest cycle whose catathermic episodes include a phase of climatic deterioration (F6) followed by a forest recurrence (F7).

ZONE G to L: between 29,40 m and 24 m, the sedimentation shows alternations of silts and more or less silty gyttja. All the pollen spectra suggest a considerable deterioration of climate with abundant heliophytes and, among the A.P., a predominance of *Pinus* pollen, which points out to the existence of small regional stands and/or long-distance transports.

ZONES H, J and L, corresponding to more organic levels, are interstadials; the two first ones are characterized by small maxima of *Betula* and *Picea*, the third one, much

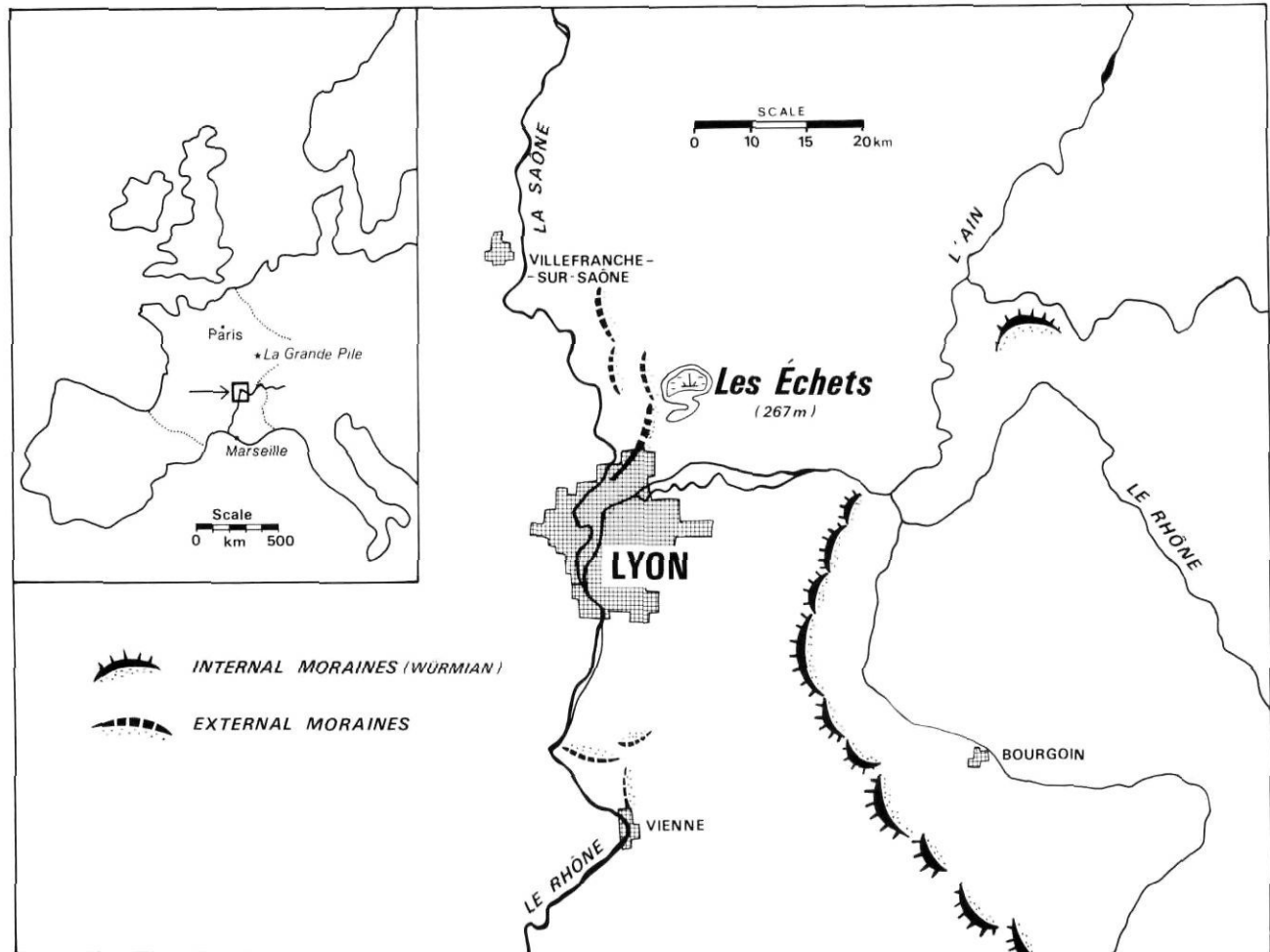


FIGURE 1. Location map of Les Échets mire.

Localisation du marais des Échets.

weaker, is only marked by a maximum of *Pinus* and a peak of *Juniperus*.

ZONES M, N, O are characterized by more abundant heliophytes than zones G to L in which as a whole persist taxa requiring much humidity, such as *Calluna*, *Filipendula* and *Sanguisorba officinalis*.

There is no indication of interstadials in these zones from the Upper Pleniglacial, dated with ^{14}C . Toward 15 000 BP, a marked increase in *Artemisia* percentages indicates a denser steppe cover, reducing the part played by long-distance pollen transports. This event suggests a climatic improvement, recorded also at sites in southeastern France (BEAULIEU *et al.*, 1983).

CORRELATION WITH GRANDE PILE

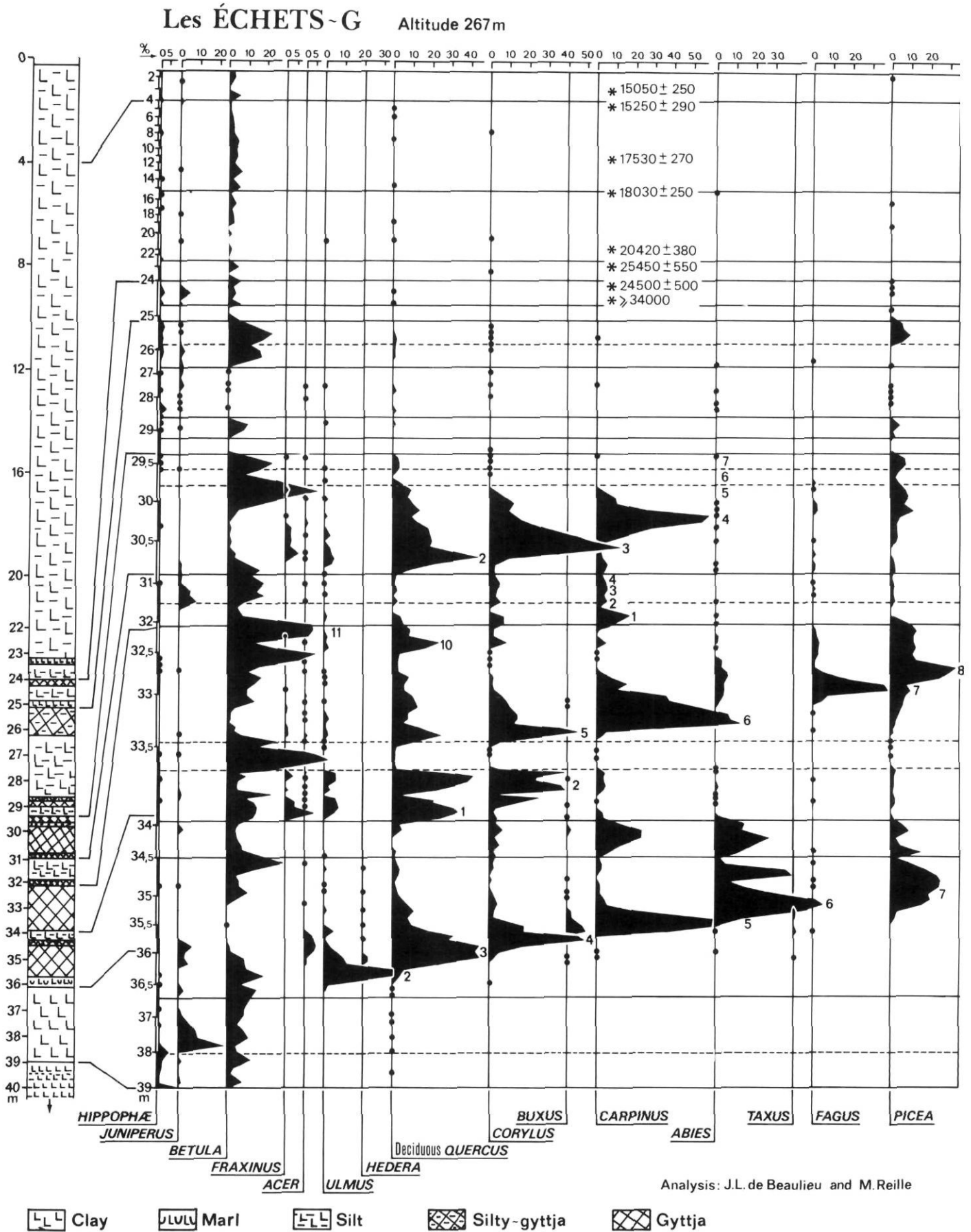
a) Below 29,40 m, lithologic as well as biostratigraphic correlations with Grande Pile are quite obvious. At both sites, the well-marked Eemian is followed by two forest cycles divided by woodless stadial episodes corresponding to a rather thin sedimentation of short duration. The optimum of both cycles is marked by *Carpinus* expansion; at Les Échets, perhaps even more clearly than at Grande Pile, the older cycle includes a cool intermediate episode (D3 and 4) without any change

in the lithology. Therefore, the equivalences noted on the right of the diagram (Fig. 2) are evident. But Les Échets sequence shows several distinctive features:

- absence of a *Taxus* phase during the Eemian;
- more abundant pollen of *Abies* during the Eemian, of *Quercus* and *Corylus* during Saint-Germain Ia, of *Carpinus* during Saint-Germain Ic and Saint-Germain II;
- *Fagus* phase during Saint-Germain Ic;
- recurrence of *Abies* toward the end of the Eemian, and of *Quercus* at the end of Saint-Germain Ic, probably reflecting positive oscillations during catathermic periods;
- more modest role of *Picea*.

Except for the absence of a *Taxus* phase which may be due to a hiatus, these differences may be ascribed either to the more southern latitude of Les Échets or to the proximity of the Southern Alps and the Rhône valley as potential refuge zones for mesophilous taxa during the previous glacial.

b) Above 29,80 m, correlations with Grande Pile are much more difficult because the sedimentation rate is quite different. Zone F7, which is a prolongation of the last temperate cycle, clearly corresponds to Ognon I of Grande Pile. We share GRÜGER's doubts (1979b) concerning the existence, at Grande Pile, of the interstadials Ognon II and Ognon III



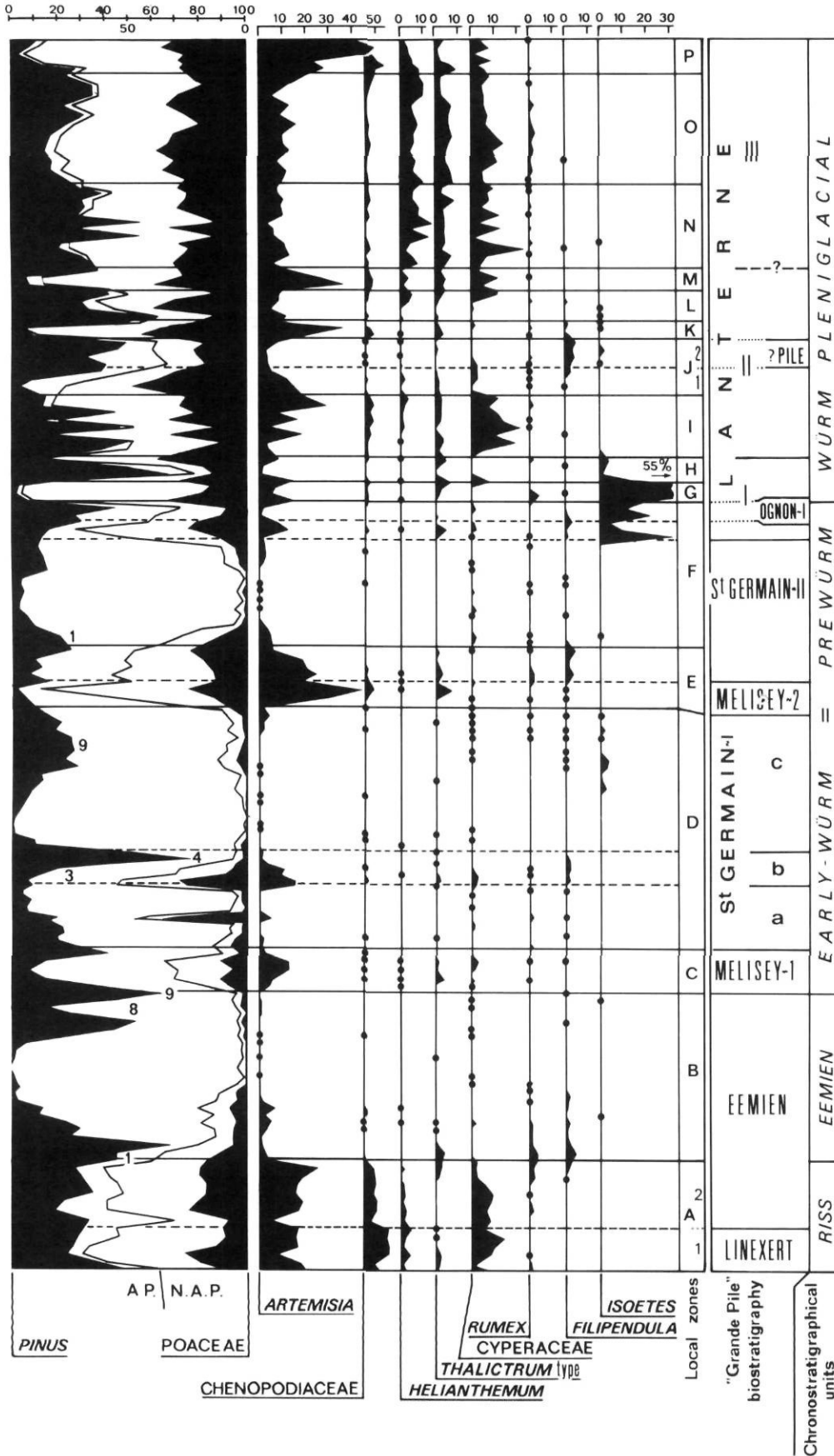


FIGURE 2. Summary pollen diagram from site G of Les Échets mire. The numbers on pollen curves correspond to sub-zones referred to in the text. A.P.: arboreal pollen; N.A.P.: non-arboreal pollen. *Diagramme pollinique synthétique du forage G du marais des Échets. Les chiffres accompagnant les courbes polliniques permettent de repérer les sous-zones mentionnées dans le texte. A.P.: pollen arboréen; N.A.P.: pollen non arboréen.*

whose pollen assemblages seem to reflect reworking phenomena. In fact, there are no equivalents of these interstadials at Les Échets. The interstadium referred to as "Pile", which corresponds to the very organic uppermost levels of the Würmian sequence and contains *Picea* pollen might correspond to zone J of Les Échets. Lastly, the general equivalences between Lanterne III and zones M-N-O-P representing the end of the Pleni-Würm, are supported by ¹⁴C datings.

COMMENTS

In many respects Les Échets and Grande Pile appear to be twin pollen sequences. Les Échets, while it confirms the general validity of the Grande Pile record, provides new data that resolve the Upper Pleistocene stratigraphic problems noted above. In particular:

1°) the local zones D and F, equivalents of Saint-Germain I and II, show more temperate vegetation, thus confirming the expected evidence of a latitudinal climatic zoning;

2°) in spite of this zoning, at Les Échets as at Grande Pile, taxa indicating a climatic interglacial optimum (*Vitis*, *Hedera*, *Ilex*, *Viscum*) are absent during the Saint-Germain episodes, which, in terms of Holocene bioclimate, places Les Échets and Grande Pile near the northern limit of extension of deciduous trees. In this respect the status of "Interglacial" for the Saint-Germain episodes can be refuted;

3°) at Les Échets, the existence of a phase of *Fagus* forest during the part of D that corresponds to Saint-Germain Ic shows that both climatic and historical factors may have controlled contemporaneous biogeographic areas;

4°) the preceding remarks support the idea that the temperate vegetation of the Saint-Germain episodes may have been contemporaneous with vegetation suggesting a much colder climate in Northern Europe. One should mention here that the correlations made by WIJMSTRA (1969) at Tenaghi Philipon between temperate episodes favourable to the expansion of oak groves (Doxaton, Drama and Eleutheropolis) and the Amersfoort, Brørup and Odderade did not raise any objections at the time;

5°) remark No. 4 undermines WOILLARD and MOOK's hypothesis (1982) that the Amersfoort, Brørup and Odderade interstadials might correspond to the interstadials Ognon I, Ognon II and Ognon III of Grande Pile, respectively;

6°) the complex forest history of cycles D and F lasted as long as the Eemian, at least for cycle D.

Therefore, we conclude that Saint-Germain Ia, Saint-Germain Ic and Saint-Germain II are equivalents of the Early Würm interstadials. But remark No. 6 leads us to suggest that the duration of ca 15 000 years attributed to these interstadials is not consistent with that of the Saint-Germain episodes. We are convinced that biostratigraphic arguments should prevail over datings and we consider that the chronology established by Woillard and Mook must be acknowledged and that, consequently, the Early Würm should be placed between 115 000 and 70 000 BP thus contradicting the generally admitted ages for this period.

This view is confirmed by the following points:

1. WOILLARD (1978) showed a correlation between Grande Pile and deep sea cores sequences; the chronology of the latter is in agreement with Grande Pile dates.

2. The numerous inconsistencies in the dates supporting the "classic" chronology of the Early Würm show that in most cases these dates can be considered only as minimum ages.

3. The first results of Ionium dating give an age of 115 000 BP for the end of the Eemian and tend to give an age older than the one admitted for the interstadials at the beginning of the Würm (VOGEL, 1982; GREMMEN, 1982).

The corollary of the proposition attributing an older age to the Early Würm is that the Pleniglacial [Lower and Middle Pleniglacial according to VAN DER HAMMEN (1971)] started earlier than was formerly thought (at about 70 000 BP instead of ca 55 000 BP as had been suggested by GROOTES (1977)).

On the other hand, the pollen analyses of Grande Pile and Les Échets show that the Early Würm is essentially made up of clearly temperate phases divided by colder shorter periods followed immediately by a continuously cold climate which lasted until the Holocene. Therefore the term "Early Würm" may in some respect seem incorrect; the term "Pre-Würm" would probably be more appropriate.

Though our propositions have raised new, unsolved problems, it is most desirable that the long continuous sequences from the European Upper Pleistocene should constitute the basis of a confrontation of the regional stratigraphic conceptions, leading to a refinement of ideas about the latest Glacial.

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