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OBSERVATIONS CONCERNING THE EXTENT AND CHRONOLOGY OF THE LATE-GLACIAL DEGLACIATION STAGES IN THE SOUTHERN FRENCH ALPS ON THE BASIS OF TWO POLLEN DIAGRAMS

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ABSTRACT

Sediments of two filled-in lakes (Terres Plaines, altitude 2,100 m; Restefond, altitude 2,400 m, Alpes-de-Haute-Provence) from the intra-alpine part of the Southern French Alps were pollenan-alytically investigated.

These sediments are indirectly dated by a comparison with C14-dated records in adjacent areas. For chronological purposes comparison of site zones, based on common trends of pollen curves within the region is more useful than the application of zone systems from other parts of Europe, such as the commonly used zone scheme of Firbas (1949). The picture of late-glacial deglaciation fits generally into the scheme proposed by Jorda (1983 a, 1986). The palynological data indicate that in a SW-exposed valley (Restefond) deglaciation at 2,400 m altitude took place already before the Allerød interstadial, clearly earlier than in a N-exposed valley (Terres Plaines) at 2,100 m.

Key-words : French Alps, Würm, late-glacial, deglaciation, palynology, chronology, glacial geomorphology.

RÉSUMÉ

OBSERVATIONS SUR L'AMPLEUR ET LA PRÉCOCITÉ DE LA DÉGLACIATION TARDIGLACIAIRE DES ALPES DU SUD À LA LUMIÈRE DE DEUX SONDAGES POLLINIQUES

Deux diagrammes polliniques des sédiments de deux lacs anciens (Terres Plaines, altitude 2 100 m; Restefond, altitude 2 400 m, Alpes-de-Haute-Provence), dans la région intra-alpine des Alpes Françaises du Sud sont décrits.

Les deux diagrammes sont datés indirectement par une comparaison avec des datations-C14 de régions limitrophes. En ayant pour objectif une chronologie il apparaît, que la comparaison aux 'site-zones', fondés sur les tendences communes des courbes polliniques de la région est plus fonctionnelle que la comparaison aux zones de Firbas. Les données palynologiques indiquent que dans une vallée exposée au SE à une altitude de 2 400 m (Restefond), la déglaciation a eut lieu durant l'interstade de Allerød, clairement plus tôt que dans une vallée exposées au N (Terres Plaines) à 2 100 m.

Mots-clés : Alpes Françaises du Sud, Würmien, tardi-glaciaire, déglaciation, palynologie, chronologie, géomorphologie glaciaire.

1. INTRODUCTION

A model describing the fluctuations of the Post-Würmian deglaciation phase has been established by Jorda (1983 a). The model is based on the relations of geomorphological characteristics of (peri-) glacial landforms and on data obtained from sediments deposited on valley floors and behind morainic ridges. The values for the parameters in this model have been modified for intra-alpine valleys by Jorda

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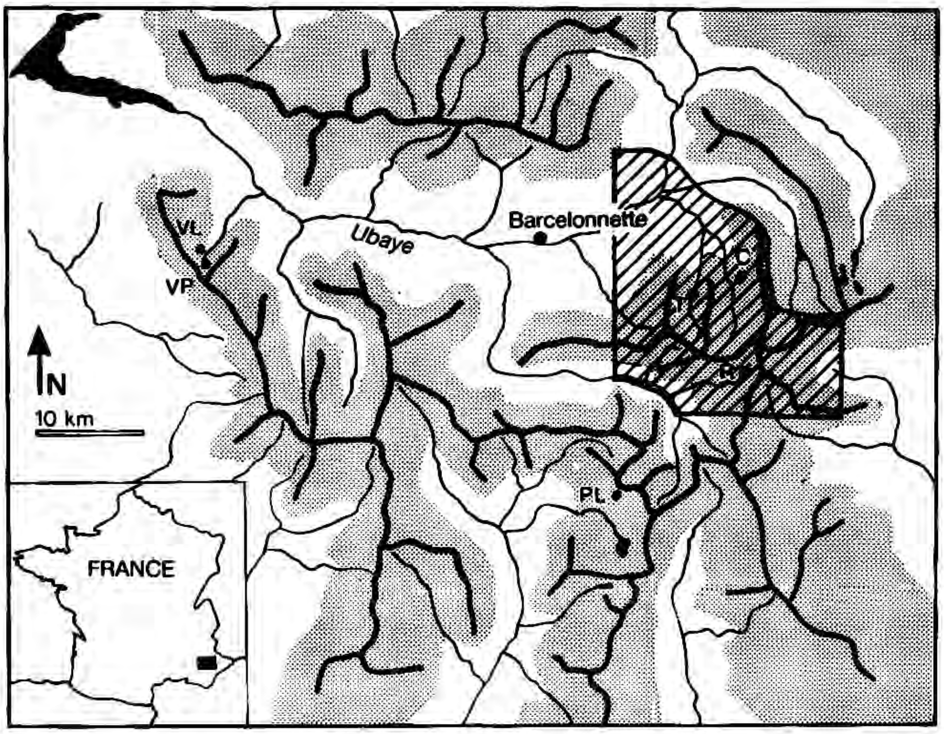


T – Terres Plaines (2100 m)
R – Restefond (2400 m)
C – Clapouse (2100 m)

VP – Vallon du Provence (2075 m)
VL – Vallon du Loup (2010 m)
PL – Plan du Laus (2120 m)

crestline
crête

altitude › 2000 m

Fig. 1. – Region of Barcelonnette (Alpes-de-Haute-Provence, France).
The stiped area indicates the position of the geomorphological map of figure 2.

Région de Barcelonnette (Alpes-de-Haute-Provence, France).
La zone hachuré indique la situation de la carte géomorphologique de la figure 2.

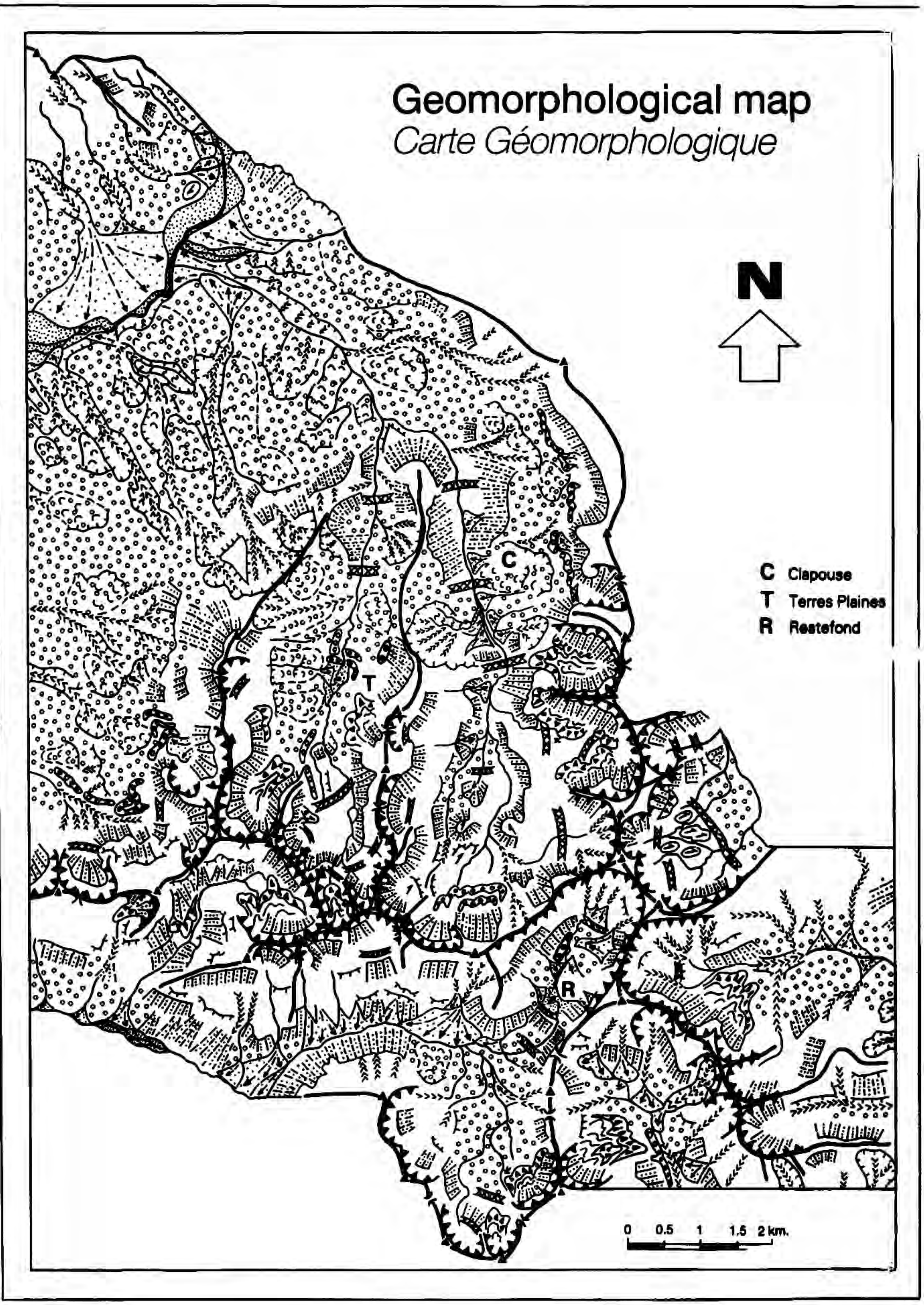
(1983 a, 1986). Only one of the pollen diagrams used by Jorda is situated in the region of Barcelonnette (pollen diagram La Clapouse, Wegmüller, 1977) (fig. 1). The purpose of our study is to obtain additional palynological data with special reference to the deglaciation history of this region. We therefore examined two sites southeast of Barcelonnette. The palynological data obtained are compared with the diagrams of De Beaulieu (1977) and Wegmüller (1977) and with the results of Jorda (1983 a, 1986).

2. STUDY AREA AND SAMPLING

The cores were taken in two hanging valleys southeast of Barcelonnette (fig. 1). The geomorphology of the area is shown in figure 2. According to the climatic zonation model of Ozenda (1985) the valleys are situated within the intra-alpine zone (low precipitation and high continentality, fig. 3).

In the valley of Terres Plaines (altitude 2,100 m, fig. 1) several morainic ridges are found including a large complex of end moraines on the bottom of the valley floor. At the southern side of this barrier deposits of a completely filled-in lake are present in which the core was taken. At the maximum core depth of 11.60 m the bottom of the lake fill was not yet reached. The lower part of the deposits consists of soft laminated clay, the upper part of peat. These deposits are irregularly intercalated by bands of silt and gravel due to the activity of small streams from the valley slopes.

The core of the smaller valley of Restefond (altitude 2,400 m, fig. 1) is taken in a depression fill behind a glacially formed rock bar. The maximum core depth in the lake was reached at a depth of



Geomorphological map
Carte Géomorphologique
N
C Clapouse
T Terres Plaines
R Restefond
C
T
R
0 0.5 1 1.5 2 km.

7.20 m in firm sandy deposits. The sediments of this fill consist in the lower part of laminated clay and silt, and of layers of peat and clay in the upper part. In this valley a small lateral morainic ridge is found at an altitude of ± 2,430 m.

Both valleys are located in the alpine zone ranging here from 2,200 to 2,800 m. The local treeline is located at ca. 500 metres below the lowest part of the valley of Restefond. The bottom of the valley of Terres Plaines is also treeless although it is situated much lower. This is due to extensive deforestation and grazing since the last centuries.

3. TREATMENT OF THE SAMPLES

Cores were taken with a Dachnowski sampler Ø 3 cm, length 30 cm). The samples were analysed in the Laboratory of Palaeobotany and Palynology in Utrecht, The Netherlands. The treatment of the samples included : solution of carbonates with HCl (30 %), wet sieving (250 µm meshes), clay dispersion and dissolution with sodium-pyrophosphate, removal of organic materials with warm KOH (10 %), solution of silica with HF (30 %), removal of remaining organic materials with H_2O_2. The samples were acetolysed at 95 °C for 7 minutes and, after dehydration, stored in silicon-oil (2000 CS).

4. CONSTRUCTION OF POLLEN DIAGRAMS

The pollen diagrams are shown in figure 4. The pollen types are ordered according to first appearance in the diagrams.

The pollen sum comprises the pollen types that originate from trees, shrubs and the terrestrial NAP. Pollen (and spore) types originating from plants

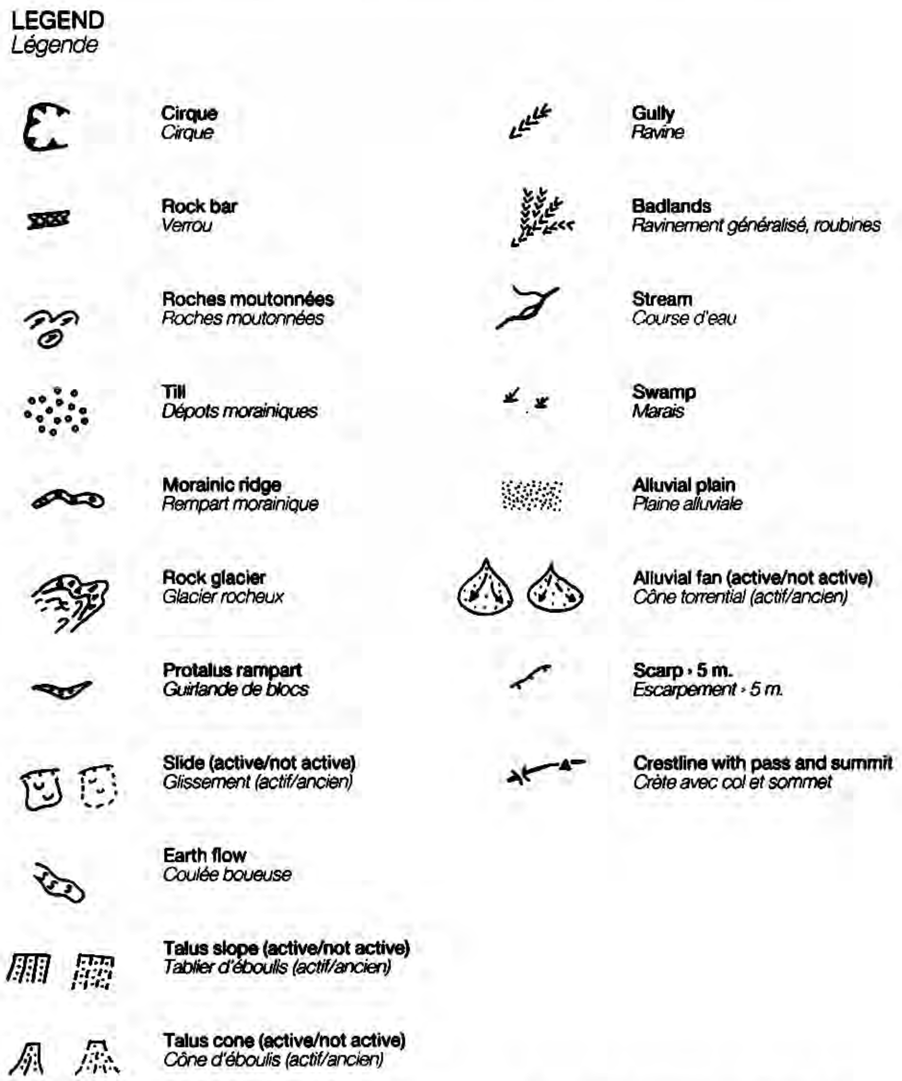


Fig. 2. – Geomorphological map of the investigated area (for location see figure 1).

Carte géomorphologique de la région étudié (localisation, voir figure 1).

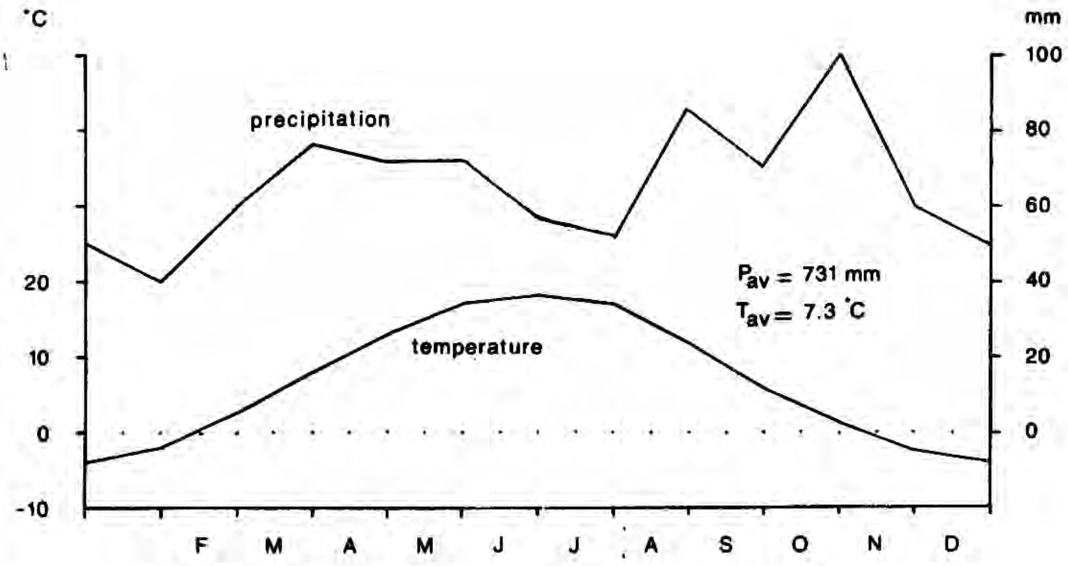


Fig. 3. – Climatological characteristics of Barcelonnette (altitude 1 130 m).
Caractéristiques climatologiques de Barcelonnette (altitude 1 130 m).

which potentially could have grown close to the coring site and would therefore exhibit (extra) local pollen values (in the sense of Janssen (1966, 1973)) were not included. These comprise Cyperaceae, aquatics and some "ferns". Also pollen types from families which are ecologically divers have been excluded from the pollen sum.

It can be difficult to establish a clear division between local and regional pollen types. Cyperaceae, for example, show in the lower part of the diagram values indicating a regional source, but in the upper parts they clearly exhibit local variability. In the diagrams of De Beaulieu (1977) and Wegmüller (1977) the pollen sum comprises all pollen types with the exception of the water plants and, as in Vegmüller, of the Cyperaceae when these reach very high values. As a result, the curves of the regional pollen types often show fluctuations partly caused by changes in local vegetation.

5. POLLEN ZONES

In order to establish a framework for interpretation and correlation with other diagrams (De Beaulieu, 1977; Wegmüller, 1977), the pollen diagrams Terres Plaines and Restefond have been zoned according to two types of zones. Site assemblage zones are recognised only for one site, either Terres Plaines or Restefond. These zones are designated as zones TPL- and RES-. Zones that can be recognised in both diagrams are designated as assemblage zones A - F and H - I.

No C-14 dates are available, but a chronology can be established by a comparison with radio-carbon dated pollen diagrams (De Beaulieu, 1977; Wegmüller, 1977) in the surrounding southern French Alps. Such a correlation in time between site zones and zones in other diagrams is possible since the site zones are based on the fluctuations in the regional pollen curves. However, in the pollen diagrams of De Beaulieu (1977) and Wegmüller (1977) the zone system established by Firbas (1949, 1954) for central Europe has been applied. As the Firbas zones are often (implicitly) connected to both their pollen assemblages and assumed chronology, confusion between biostratigraphical and chronostratigraphical correlation may arise. For that reason the assemblage zones were established to separate strictly biostratigraphy and chronology (Janssen, 1980). In this way circular reasoning is avoided when one compares zones defined elsewhere in Europe followed by a correlation in time on the basis of these zones.

6. DEFINITION OF THE POLLEN ASSEMBLAGE ZONES OF RESTEFOND AND TERRES PLAINES

The assemblage zones recognised in both diagrams are defined according to their common characteristics (tab. 1). In addition to these definitions the following remarks must be added :

— Zone A is only represented in the diagram of Restefond; the lowest zone of the diagram of Terres Plaines is zone B.

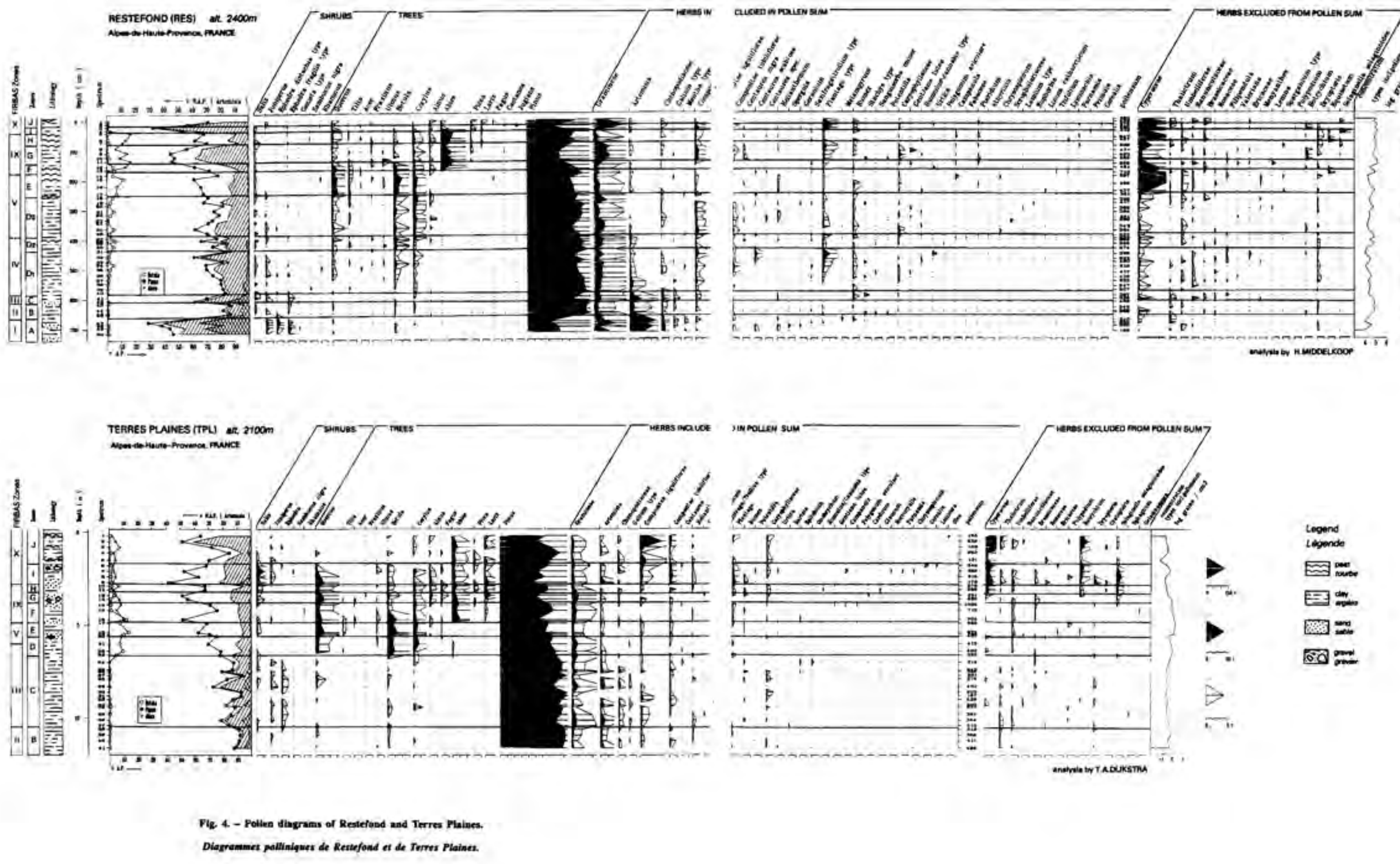


Fig. 4. – Pollen diagrams of Restefond and Terres Plaines.

Diagrammes polliniques de Restefond et de Terres Plaines.

— Zone D may be not completely present in the diagràm of Terres Plaines, since at this depth coarse gravelly material has been deposited on top of the argillaceous lake sediments. Zone TPL-D embraces only 4 spectra and a hiatus may be present at the zone boundary D/E. The division of zone D into three subzones is based on the diagram of Restefond.

— Gaps in the pollen record may also occur in the upper holocene part of the diagrams, but these are not relevant for the problem concerned with in this paper. These gaps prevent the establishment of a clear pollen stratigraphy. However, a complete sequence of assemblages is present in the pollen diagram La Clapouse (Wegmüller, 1977). The zones G-J in the diagrams of Restefond and Terre Plaines are recognised on the basis of comparison with the assemblages in this diagram.

— The recognition of gaps in the pollen diagrams is based on the (chronological) zone scheme of Firbas. It remains to be seen whether gaps will manifest themselves when a chronology exists based on regional pollen assemblages of a region of limited extent. For such a chronology the data of just two pollen diagrams are not sufficient, and additional palynological data must be awaited.

Table 1. - Description of the pollen-assemblage zones of Terres Plaines and Restefond.

Description de l'assemblage pollinique de Terres-Plaines et de Restefond.

Zone A : Juniperus-Artemisia-Ephedra assemblage zone.

The assemblage of this zone is characterized by the low values of the AP (40 % - 50 %), where *Pinus*, *Juniperus* and *Ephedra* are the most important components. The NAP dominates with values up to 70 %; prominent pollen types are Gramineae, *Artemisia* and Chenopodiaceae.

Zone B : Pinus-Gramineae assemblage zone.

Pinus is the dominant pollen type in this zone; compared to zone A, the curve of *Pinus* has increased rapidly to more than 80 %. The composition of the NAP is similar to zone A, but the percentages are lower : only Gramineae and *Artemisia* attain values above 5 %.

Zone C : Pinus-NAP assemblage zone.

The values of *Pinus* are lower than in zone B, whilst *Salix*, *Juniperus* and *Ephedra* occur more frequently (〉 1 %). The curves of Gramineae, *Artemisia* and Chenopodiaceae have increased to more than 5 %.
The irregular shape of the curves of *Pinus* and the NAP in the diagram Terres Plaines is mainly due to differences in state of corrosion of the material.

Zone D : Quercus-Betula-Corylus assemblage zone.

In zone D *Quercus*, *Betula* and *Corylus* become regular components, first with low values, in the upper part increasing to more than 4 % each. *Tilia*, *Ulmus*, *Acer*, *Fraxinus* and *Alnus* are occasionally present.

Subzone RES-D1

In the lower part of this subzone *Pinus*, *Artemisia* and Chenopodiaceae still have relatively high values like in zone C. The curves of *Quercus*, *Betula* and *Corylus*, and those of the other herbs do not increase below the upper part of this zone.

RES-D2 :

This small zone differs from the adjacent zones by maxima of *Pinus* frequencies, a minimum in the curve of *Corylus*, and a remarkable increase of *Artemisia* values to more than 2 %. The other NAP-types occur less frenquently than in the zones RES-D1 and RES-D3.

Subzone RES-D3 :

The lower boundary is marked by a clear increase in the curve of *Corylus*, which regularly attains values of about 4 %. *Alnus* is occasionally present, and the continuous curve of *Tilia* sets in *Artemisia* almost has disappeared, whilst other components of the NAP, Compositae, Caryophyllaceae, *Rumex* and *Plantago* become more abundant (〉 1 %).

Zone E : Quercus-Betula assemblage zone.

This zone is characterized by the occurrences of maxima in the curves of *Quercus* and *Betula*; their frequencies exceed 7 %. In the upper part of zone E *Tilia* and *Alnus* frequencies attain maximum values of about 1 %, and the first pollen grains of *Abies* are present. The values of the NAP, which mainly consists of pollen of Gramineae are lower than in zone D.

Zone F : Abies-Corylus assemblage zone.

The characteristic pollen type of this zone is *Abies* : At the lower boundary of the zone the curve presents a sharp increase to values above 10 %. The frequencies of *Corylus* remain regular, but the curves of *Quercus*, *Betula*, *Tilia* and *Pinus* decrease steadily.
The NAP (Gramineae) frequencies increase.

Zone TPL-G : Larix-Quercus-NAP assemblage zone.

The main characteristics of this zone are the increase of *Larix* pollen frequencies and the maximum of *Quercus* values (12 %). *Corylus*, *Betula* and *Alnus* occur regularly, whilst the values of *Pinus* and *Abies* decrease.
Of the NAP the Gramineae frequencies attain a maximum of more than 10 %. Remarkable is the onset of the increasing values in the curves of *Botrychium* and *Selaginella selaginoïdes*.

Zone RES-G : Larix-Picea-NAP assemblage zone.

This zone is characterized by a strong decrease of the AP frequencies : compared to the adjacent zones, *Pinus*, *Abies*, *Quercus* and *Alnus* frequencies have decreased to lower values. In the upper part of the zone the onset of the continuous curves of *Picea* and *Larix* and the first pollen grains of *Castana* are found. Of the NAP types Gramineae, Compositae, *Plantago*, *Rumex* and Caryophyllaceae are prominent; the curve of *Botrychium* presents a maximum of more than 1 %.

Zone H : Pinus-Abies assemblage zone.

The frequencies of *Pinus* and *Abies* have increased rapidly and attain maximum values. The NAP curves present low values.

Zone I : NAP assemblage zone.

Zone I is dominated by the NAP : Gramineae, *Artemisia*, Compositae, *Plantago* and *Cerealea* are prominent. The AP curve decreases to a minimum. Only the curves of *Picea* and *Larix* *increase slightly in the upper part of this zone. Fagus*, *Castanea* and *Juglans* become regular components with low values.

Zone TPL-J : NAP assemblage zone.

This zone comprises in the diagram of Restefond only two spectra, characterised by an increase of *Pinus* frequencies. The upper part of the pollen diagram Terres Plaines is characterized by strong fluctuations in the curves of the coniferous pollen types. The pollen frequencies of *Quercus*, *Betula*, *Corylus* and *Fagus* decrease to low values and are irregularly present.
NAP is an important component of the pollen assemblage : pollen of Gramineae, *Artemisia*, *Plantago*, Compositae and also of *Botrychium* is abundant.

7. INTERPRETATION OF THE POLLEN ASSEMBLAGES

The zones A - C reflect a typical late-glacial assemblage with a predominantly steppe vegetation with *Artemisia* and *Juniperus*. Zone B shows a rapid expansion of *Pinus* forest. A deterioration of the climate in zone C is indicated by opening up of the pine forest and expansion of steppe plants.

The lower boundary of zone D marks the beginning of the Holocene : after a short period with still relatively high percentages of *Artemisia*, the thermophilous trees *Quercus* and *Corylus* immigrate into the valleys of the southern French Alps. The maximum extent of this deciduous forest is recorded in zone E. Zone F reflects the rapid expansion of *Abies*, partly replacing the *Quercus* forest in the montane zone.

The zones G - J can be interpreted as an alternation of cultural phases and periods in which forests expanded. Zones G and I are characterized by the occurrence of pollen types associated with cultural phases, such as *Plantago*, *Rumex*, Gramineae, Compositae, *Botrychium*, some grains of Cerealia, the heliophylous tree *Larix* and (in zone RES-I) *Castanea* and *Juglans*. The zones H and part of zone J, characterized by low values of NAP, reflect periods of re-expansion of the forest.

The diagram of Restefond shows higher values of NAP and a better reflection of minor vegetation changes above the treeline. In the diagram of Terres Plaines higher values of pollen from deciduous trees from the montane zone and earlier occurrence of *Larix*, *Picea* and *Fagus* is found.

These differences are mainly related to the topographical differences between both valleys. The peatbog in the valley of Restefond is situated at a 400 m higher altitude than the lake-fill in the valley of Terres Plaines, and it is isolated by high mountain ridges from the lower vegetation zones. Probably, for most of the time covered in the diagram, it has been located above the tree line. The alpine non-forest vegetation is therefore stronger reflected in the pollen assemblages of Restefond than in those of Terres Plaines. Tree species, of which the pollen is dispersed relatively over short distances (*Larix*, *Picea*, *Fagus*), are recorded later when they gradually immigrated into the Southern French Alps.

The valley of Terres Plaines is situated within the wide basin of Barcelonnette, close to the montane and colline vegetation zones (Gobert *et al.*, 1964) in the Ubaye valley. Changes in vegetation within these zones (*Quercus*, *Fagus*) are recorded earlier than in the diagram of Restefond.

A bioclimatic separation of vegetational events at different altitudes is not yet possible because the two sites are situated in two valleys which are differently exposed on either side of a water divide.

8. CORRELATION OF THE SITE ZONES WITH POLLEN ASSEMBLAGES IN DIAGRAMS FROM ADJACENT REGIONS

The pollen assemblages of the site zones in the diagrams of Terres Plaines and Restefond have been correlated with the pollen assemblages in the diagrams Vallon de Provence (2,075 m) (De Beaulieu, 1977), Vallon du Loup (2,010 m) (De Beaulieu, 1977), Plan du Laus (2,120 m) (De Beaulieu, 1977) and La Clapouse (2,100 m) (Wegmüller, 1977) (fig. 1).

Late-Glacial

The pollen assemblages of zones A and B can be correlated with those in zones I resp. II in the diagrams Vallon de Provence and Vallon du Loup. It is difficult to determine to which level the lower boundary of zone (RES-) A belongs, because the lower part of zone I is not completely present in these diagrams. As zone Ic generally appears to be hardly developed in the Southern French Alps (Borel *et al.*, 1984), it is likely that the lower boundary of the pollen diagram of Restefond can be placed biostratigraphically within zone Ib.

Zone C, with its upper boundary marking the end of the Pleistocene, corresponds well with zone III in all other diagrams.

Holocene

The main characteristic of zone D, the consistent rise of the curves of *Quercus*, *Betula* and *Corylus*, occurs in all other diagrams in zone IV. It is remarkable that the relatively high values of *Artemisia* below the level where the pollen frequencies of the thermophilous trees start to increase are found in both the pollen diagrams of Restefond and Vallon de Provence. It shows that this assemblage, indicating a still relatively cold climate, is not as unique as was assumed by De Beaulieu (1977). However, to assign this assemblage to an equivalent of the Piottino phase (Behre, 1967) is premature as long as it is not present and dated in more diagrams.

According to De Beaulieu (1977) and Wegmüller (1977) it is difficult to recognise the boundary between Firbas' zones IV and V on the basis of differences in pollen assemblages in most of the diagrams from the Southern French Alps. In some cases this boundary has been assessed by means of interpolating 14-C dates or even on the basis of changes in lithology. However, in the pollen diagram of Restefond a distinct increase of *Corylus* pollen frequencies is found at 394 cm depth, marking the beginning of zone RES-D3. This coincides with an important change in composition of the NAP, where *Artemisia* pollen almost disappears. From this it can be concluded that zones RES-D1 and RES-D2 correlate with zone IV.

The pollen assemblages of zones RES-D3 and E correlate well with zone V.

The lower boundary of zone F, characterised by the steep increase in the curve of *Abies*, correlates clearly with that of zone VI in the diagrams Vallon de Provence, Vallon du Loup and Plan du Laus. Wegmüller (1977) assigned the beginning of zone VI in the pollendiagram La Clapouse at a lower level, where the continuous curve of *Abies* begins, although with low values. The different pollen assemblage of zone VI in the diagram La Clapouse is a consequence of his chronological interpretation of Firbas' zone VI at this level. Wegmüller (1977) assumes that the beginning of the continuous curve of *Abies* in the diagram La Clapouse corresponds chronologically with the explosive expansion of *Abies* in the surrounding regions as shown in the diagrams Vallon de Provence, Vallon du Loup and Plan du Laus (De Beaulieu, 1977). Wegmüller argues that *Abies* colonized only slightly later the area around Barcelonnette. However, neither dates, nor the pollen assemblages in our diagrams can confirm this interpretation. Again, this shows the difficulties in the application of the zone system of Firbas to this part of the Southern Alps.

The correlation between the zones G - J and corresponding levels in the diagram La Clapouse is indicated in figure 5. The assessment of these zones is mainly based on the various cultural phases wich were recognised by Wegmüller (1977); here too the zonation scheme of Firbas appears to be less appropriate to apply in pollen diagrams of the Southern French Alps.

La Clapouse			TPL	RES
depth (cm)	cultural phase	Firbas zones	zones	
10-70	*recent deforestation*	X	J	J
70-110	*Late Middle Age*		I	I
110-130	*reforestation*		H	H
130-230	*Iron Age-Roman-Early Middle Age*	IX	—	RES-G
230-310	*Bronze Age*		TPL-G	—

Fig. 5. – The correlation of zones G-J and corresponding levels in the diagram of Clapouse (Wegmüller, 1977).

Corrélation des zones G-J et niveaux correspondants dans le diagramme de Clapouse.

9. CHRONOLOGY

The C-14 dates from the pollen diagrams from the surrounding regions and the chronological boundaries of the geological periods (according to Borel *et al.*, 1984, fig. 6) are connected with levels in the diagrams of Terres Plaines and Restefond on the basis of biostratigraphical correlation.

It should be realised that biostratigraphically equivalent levels in different diagrams are by definition not necessarily of the same age. However, for the purpose of our investigations this procedure may be adequate : we are mainly interested in the identification of the major climatic and vegetational stages during Late-Glacial and Early Holocene. Previous investigations in this area indicated that with respect to the required accuracy these major stages can be considered to be isochronous (De Beaulieu, 1977; Wegmüller, 1977; Borel *et al.*, 1984).

Our interpretation of the chronology of the diagrams of Terres Plaines and Restefond is shown in two time-depth curves (fig. 7).

10. RECONSTRUCTION OF GLACIAL STAGES DURING THE LATE GLACIAL

Jorda (1983 a) combined the glacial stages in the southern French Alps found by Schweizer (1968) with the results of his own geomorphological investigations; the palynological studies of De Beaulieu (1977) and Wegmüller (1977) enabled him

Firbas zones		Age yr.BP
X	Subatlantic	
IX		
		2.800
VIII	Subboreal	
		4.500
VII	Atlantic	
VI		
		7.500
V	Boreal	
		8.900
IV	Preboreal	
		10.300
III	Youngest Dryas	
		10.800
II	Allerod	
		11.800
Ic	Younger Dryas	
		12.400
Ib	Bolling	
		13.300
Ia	Oldest Dryas	

Fig. 6. – Chronology of Late- and Postglacial (after Borel *et al.*, 1984).

Chronologie du Tardi- et Postglaciaire.

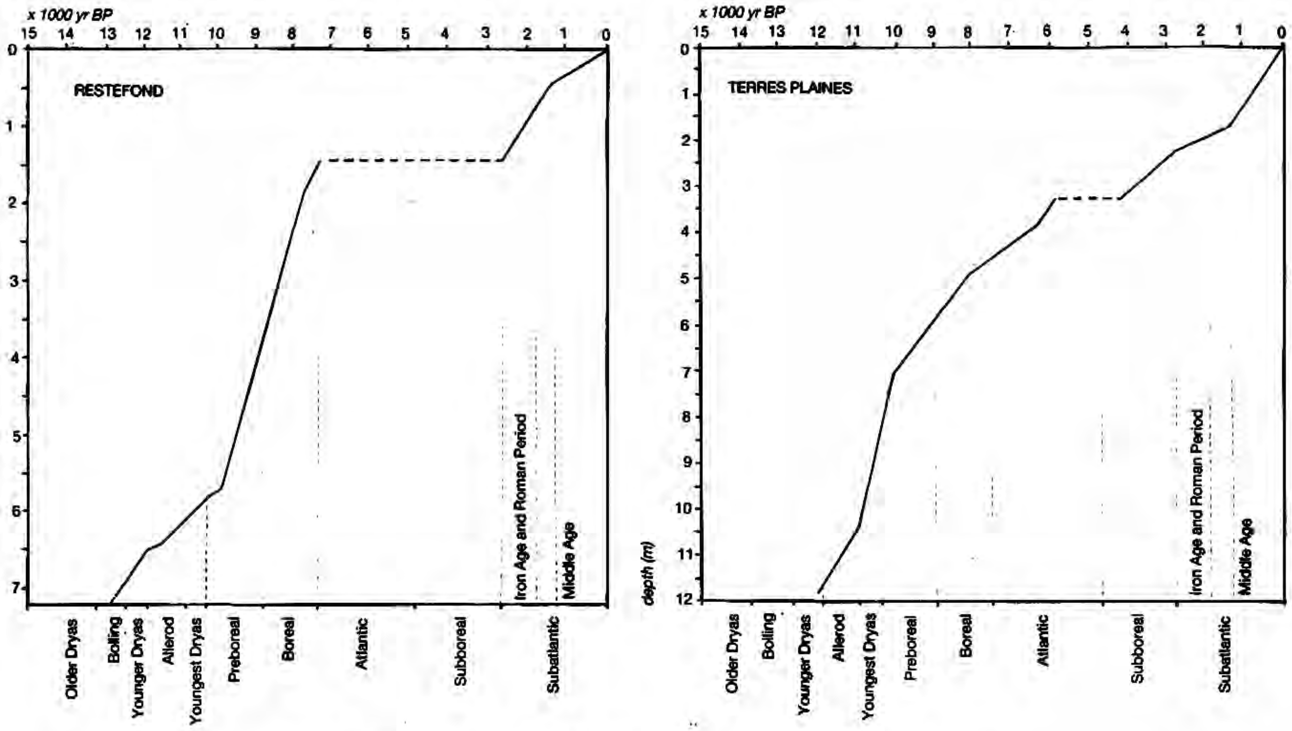


Fig. 7. – Reconstructed Time/Depth curves of Terres Plaines and Restefond.
Courbes synthétiques Temps/profondeur de Terres Plaines et de Restefond.

to identify climatic oscillations and provided a chronological framework. He presented the result of his investigations in a scheme in which he summarises the climatological, vegetational and geomorphological development of the glacial and periglacial environment ("Glaciaire d'altitude") in the Alpes-de-Haute-Provence during the Late-Glacial and Holocene. In this model, 6 glacial stages are described by means of the following parameters :

E : altitude of the frontal moraine (or glacier snout),
LN : "limite des neiges"; snow line, approximating the equilibrium line of a glacier,
DLN : decrease of the LN of a stage compared to the actual LN.

These stages and the values of their parameters are shown in figure 8.

Jorda (1983 a, 1986) argues that a climatologic contrast between the continental intra-alpine zone and the more humid extra-alpine zone existed already during the Late Glacial. One of the consequences of this difference is, that during the colder periods the glaciers were less extended in the intra-alpine zone than those in the extra-alpine zone, since there was more accumulation of snow in the latter. Therefore, LN and DLN values, different from the extra-alpine zone were proposed for the valleys inside the intra-alpine zone, adapted to the more continental climate in this area (Jorda, 1983 a : Haut-Bachelard; Jorda, 1986 : Clapouse, Terres Plaines). The values for E, LN and DLN for the intra-alpine zone are shown in table 2.

Another important parameter in the extent of a glacier is the exposition of a valley. Schweizer (1968) demonstrated that for this reason the altitude of the permanent snow-line in this area may vary more than 100 m over short distances.

10.1. – Remarks on the methodology

Before comparing the conclusions of Jorda (1983 a; 1986) with the results of our investigations in the valley of Terres Plaines and valley de Restefond, a few remarks on methodology will be made :

— Jorda (1983 a; 1986) applied the method of Höfer (1897) to calculate LN, which method is not accurate according to Gross *et al.* (1977).

— It is difficult to determine a reliable value for the actual LN : in this part of the French Alps, only a few mountains are up to 3,000 m high and attain the altitude of the permanent snow line. The few glaciers in the Alpes-de-Haute-Provence seem to be relics which have survived under local favourable circumstances. Therefore, the altitude of LN is often estimated by extrapolating climatic data (a.o. Schweizer (1968)).

STAGE	E	LN	DLN	AGE
V	2500-2650m	2700m	200m	Subatlantic
IV	2300-2250m	2650-2630m	350-400m	Preboreal
III	2200-2400m	2500m	500m	Younger Dryas
II	2100-2300m	2400m	600m	Oldest Dryas (2nd part)
I	1760m	2200-2400m	>800m	Oldest Dryas (1st part)

a. Haut-Bachelard (JORDA, 1983a, table 1, p.44)

VALLEY	E	LN	DLN
Clapouse	2250m	2600m	450m
Terres Plaines	>2300m	2600m	400m

b. Paramaters for Younger Dryas (JORDA, 1986).

E = average altitude of glacier fronts
LN = average permanent snow line
DLN = decrease of permanent snow line compared to actual permanent snow line

Table 2. – Paramaters for the intra-alpine zone (Jorda, 1983 a, 1986).

Paramètres pour la zone intra-alpine (Jorda, 1983 a, 1986).

— In the scheme of Jorda (1983 a) a general proposal for the deglaciation stages in the whole region is summarized in terms of average values of the different parameters. The geomorphological and palynological data on which the model is based, come from valleys which are situated in the extra-alpine zone (e.g. De Beaulieu et Jorda (1977)). They all have a NW-N-NE exposition and are morphologically very similar. Differences in exposition and continentality seem to cause variations in the values in Jorda's scheme which are in the same order of magnitude (50 - 100 m) as the differences between the parameters of subsequent stages. Therefore, it may be questioned whether the scheme is useful to describe the deglaciation stages of the whole region.

— Recognition and chronology of cold phases in the intra-alpine zone are – unlike for the extra-alpine zone – not based on data which are directly related with frontal moraines. Instead, the cold phases are recognised by climatic interpretation of pollen diagrams (Wegmüller, 1977), sediments (Jorda, 1983 b; 1986) and periglacial forms (Jorda, 1977; Haeberli, 1978; Barsch, 1978).

10.2. – Data from the valleys of Terres Plaines and Restefond

It was found by means of correlation with pollen diagrams of De Beaulieu (1977) and Wegmüller (1977) that the oldest deposits from the core at the site of the Terre Plaines can be assumed to date from the Younger Dryas. However, since the maximum depth of the lake fill was not reached, older lake deposits may be present. From this follows that the glaciers reached down to 2,100 m in this valley at least before the Younger Dryas time, most likely before the Allerød time.

The oldest (lake-fill) deposits at the site in the valley of Restefond can be considered to date from pre-Allerød time (fig. 7). This means that since pre-Allerød time the glacier of the Restefond never has reached as low as 2,400 m altitude.

The positions of the sites and the reconstructed minimum ages of the lowest sediments found in the cores allows to establish for these valleys minimum/maximum altitudes or youngest/oldest ages for the parameters used by Jorda (1983 a; 1986). The values have been calculated according to the methods of Jorda (1983 a). In accordance with Schweizer (1968), Dougedroit (1976), Pile (1981) and Jorda (1986), the value of the actual LN was estimated to be at ± 3,050 m in the valley of Restefond. Both valleys are located within the intra-alpine zone, but they differ in exposition :

— The valley of Terres Plaines has a N exposition; the site is situated at 2,100 m in a lake fill behind a complex of morainic ridges. The date of the oldest deposits at this site is a rough estimate of the maximum age of these morainic ridges. Therefore, this site provides an indication of the maximum age for the parameters E, LN and DLN corresponding to these moraines : A (lowest) value of E of 2,100 m and of LN of 2,400 m and a (maximum) value of DLN of 650 m have been reached at least during a stage older than the Younger Dryas.

— The site in the Vallon de Restefond is situated at a for this region relatively high altitude of 2,400 m, in a SW exposed valley. Because the peatbog in this vally is situated behind a glacial threshold, instead of being fringed at the lower side by a morainic ridge, values of E, LN and DLN corresponding to the altitude of the site can be assessed. Here the palynological data indicate that since pre-Allerød time (during stages III and IV) E always has been at a higher position than 2,400 m, LN higher than 2,550 m, and that DLN always has been less than 500 m.

VALLEY	E	LN	DLN	AGE
Restefond	>2400m	>2550m	<500m	older than Alleröd
Terres Plaines	2100m	2400m	650m	older than Younger Dryas older than Alleröd?

Table 3. – Data from the valleys of Restefond and Terres Plaines.

Données des vallées de Restefond et de Terres Plaines.

STAGE	E	LN	DLN	AGE
VI	2800m	2800m	-150m	Subatlantic, Little Ice Age
V	2500m	2700-2750m	-200m	Early Subboreal
IV	2360-2250m	2500-2600m	-400m -500m	Early Preboreal
III	2000-2200m	2250-2500m	-500m	Youngest Dryas
II	1800-2000m	2200-2400m	-600 -700m	Oldest Dryas (2 nd part)
I	1700-2000m	2100m	-800m	Oldest Dryas (1 st part)

E = Average altitude of glacier fronts
LN = Average permanent snow line
DLN = Decrease of the permanent snow line compared to the actual permanent snow line

Fig. 8. – Values for E, LN anb DLN for the extra-alpine zone according to Jorda (1983 a).

Valeurs de E, LN et DLN pour la zone extra-alpine selon Jorda (1983 a).

10.3. – Comparison with the scheme of glacier retreat of Jorda

The data from the valley of Terre Plaines and Restefond are compared to the data proposed by Jorda (1983 a; 1986) for the intra-alpine zone (fig. 9).

The values of E, LN and DLN found for the valley of Terre Plaines match with the ranges given in the scheme for stage II. This agrees with our conclusion that the moraines are formed during a (cold) period older than the Younger Dryas, bearing in mind that, since the bottom of the lake-fill was not reached, only an approximation could be made of the maximum age of these moraines.

The critical values for LN and DLN from the valley of Restefond overlap with the ranges given by Jorda for stage III. The difference for E is in the order of 50 - 100 m and, accepting Jorda's scheme, should be explained by the different exposition of the valleys. However, it must be realised that the age of stage III is younger than the oldest deposits in the core. A glacier in the valley of the Restefond which existed during stage III would correspond with higher altitudes for E and LN, and a lower DLN for this stage. These values may fall outside the range given by the scheme of Jorda. The small differences for the values proposed in the scheme of Jorda may be attributed to inaccuracies of the method. In addition, it must be realised that DLN is based on different definitions of LN : in this area the actual LN is in most places higher than the altitude reached by the mountains. Therefore, the altitude of this level is determined by means of extrapolation of temperature gradients. However, the position of the late-glacial LN is determined by the amount of snow accumulation, depending on both temperature and snowfall.

10.4. – Recognition of glacial stages

Apart from the large terminal moraine complex which forms the barrier for the lake in the valley of Terre Plaines, also lateral morainic ridges are found upstream the sites in both valleys. A direct chronological relation between the lake-fills and these moraines does not exist. The stages defined by Jorda (1983 a) can only be correlated with these morainic ridges on the basis of a comparison of the data described in the previous chapter.

The stages are considered as chronological in the two valleys.

Vallon des Terre Plaines :

— The large moraine at 2,100 m corresponds with stage II.

— The (lateral) morainic ridge descending near La Culatte down to an altitude of ± 2,200 m, may be formed during a stage younger than stage II, assuming a gradual retreat of the glacier front. It is the first morainic ridge upstream the large moraines of stage II, and it corresponds with stage III.

Vallon de Restefond :

— Morainic deposits are found downstream the site in the valley of Restefond, near the confluent with the Torrent de la Braisette. These deposits are difficult to correlate with any stage because they may be influenced by the glacier of this northern exposed valley.

— The small morainic ridge upstream the site at ± 2,450 m cannot be dated on the basis of the pollen diagram Restefond. It may correspond to stage III. However, this does not confirm nor reject the scheme of Jorda.

It is clear that more dates of moraine complexes are needed in order to determine the validity of the subdivision of Jorda's (1983 a) stages for the intra-alpine zone.

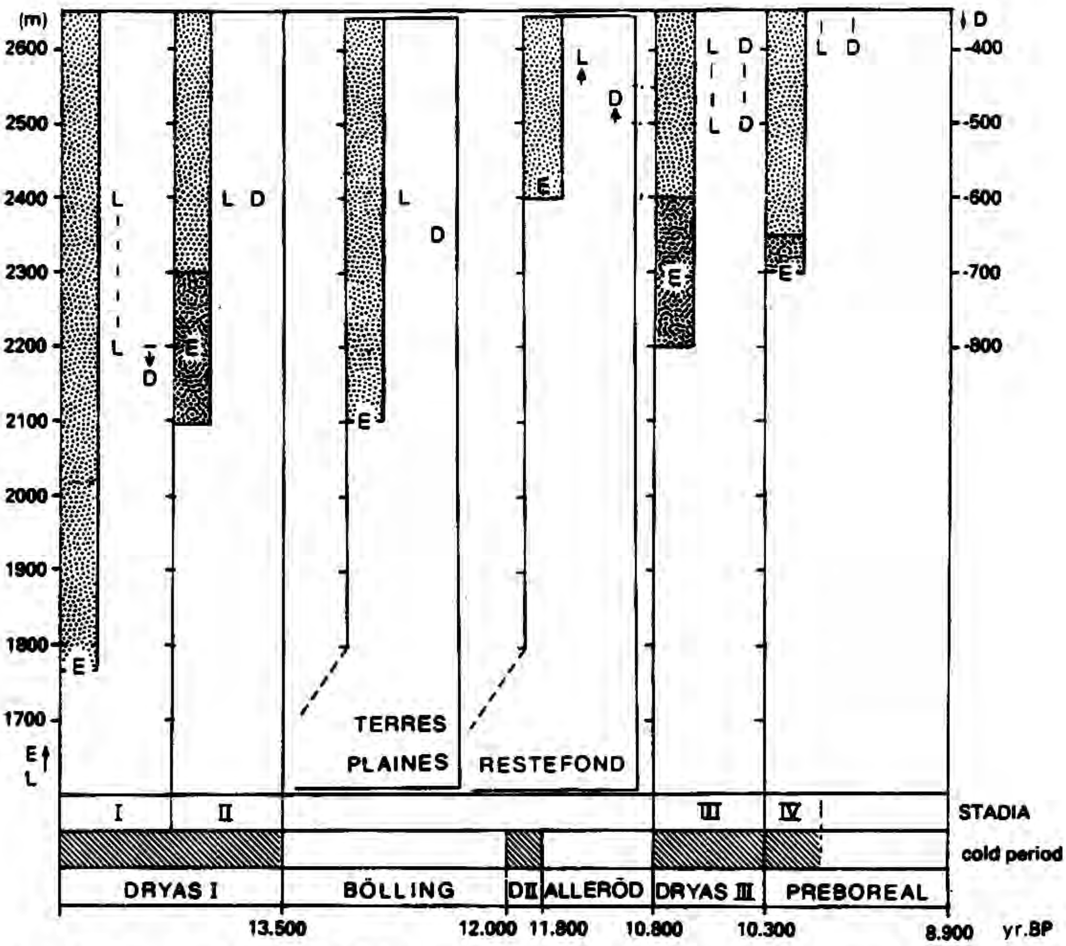


Fig. 9. – Comparison between the values of E, LN, DLN for the valleys of Terres Plaines and Restefond and those for the intra-alpine zone according to Jorda (1983 a, 1986).

Comparaison entre les valeurs de E, LN, DLN pour les vallées de Terres Plaines et Restefond et celles de la zone intra-alpine selon Jorda (1985 a, 1986).

9 – CONCLUSIONS

Palynology of the Terres Plaines and Restefond sites allowed to establish a regional zonation of pollen diagrams. The pollen zones coïncide with the zonation established by Firbas (1949) for Central Europe. In the upper Holocene part of the diagrams application of the Firbas zonation in this area is met by practical and theoretical problems. Further work should be carried out to define proper regional pollen zones for this area.

The palynological data provided new observations concerning the late-glacial deglaciation history of the Southern French Alps. In general they seem to confirm the corrected values of Jorda (1983 a, 1986), in addition to the general deglaciation scheme. It was shown for the valleys of Terres Plaines and Restefond that the extent of the post-Würm glaciers might have been substantially less in the intra-alpine zone in S-exposed valleys than in N-exposed valleys, and deglaciation took place earlier than in the extra-alpine zone.

In the use of tracing deglaciation stages in the southern French Alps, the general scheme based on average values of the parameters must be corrected for exposition and degree of continentality in order to bring in fine detail. This calls for considerable additional palynological and geomorphological research.

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Observations concerning the extent and chronology of the Late-Glacial déglaciation stages in the Southern French Alps on the basis of two pollen diagrams

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Deux diagrammes polliniques des sédiments de deux lacs anciens (Terres Plaines, altitude 2 100 m; Restefond, altitude 2 400 m, Alpes-de-Haute-Provence), dans la région intra-alpine des Alpes Françaises du Sud sont décrits. Les deux diagrammes sont datés indirectement par une comparaison avec des datations-C14 de régions limitrophes. En ayant pour objectif une chronologie il apparaît, que la comparaison aux 'site-zones', fondés sur les tendences communes des courbes polliniques de la région est plus fonctionnelle que la comparaison aux zones de Firbas. Les données palynologiques indiquent que dans une vallée exposée au SE à une altitude de 2 400 m (Restefond), la déglaciation a eut lieu durant l'interstade de Alleröd, clairement plus tôt que dans une vallée exposées au N (Terres Plaines) à 2 100 m.