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Chronostratigraphic relationships of tephras, pollen features, and ^{14}C dates in the French Massif Central and in the Eifel (Germany)

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Preliminary remarks. (i) For the detailed results summarized in this abstract see Juvigné et al. (1994a) and Juvigné et al. (1994b). (ii) Chronostratigraphy is discussed in ^{14}C years B.P. throughout this paper.

1. Reliability of ^{14}C dates estimated by discussing the data available for the Laacher See Tephra

Eighteen ^{14}C dates concerning the tephra of the Laacher See volcano (Eifel/Germany) were found in different papers (all dates in yr B.P.): #1, 11,500 ± 120; #2, 11,380 ± 435; #3, 11,305 ± 480; #4, 11,200 ± 420; #5, 11,150 ± 200; #6, 11,080 ± 160; #7, 11,030 ± 160; #8, 11,025 ± 90; #9, 10,960 ± 90; #10, 10,950 ± 190; #11, 10,935 ± 475; #12, 10,880 ± 95; #13, 10,830 ± 45; #14, 10,820 ± 150; #15, 10,800 ± 300; #16, 10,715 ± 200; #17, 10,680 ± 85; #18, 10,640 ± 130 (detailed references in Juvigné et al. 1994a)

It was demonstrated that the eruption of the Laacher See volcano (East Eifel, Germany) lasted only a few days (Bogaard, 1983; Bogaard & Schmincke, 1985), but the time range corresponding to the difference between the extreme ^{14}C dates (#1 and #18) is 860 years. The characteristics of the dated samples should be responsible for the major part of the deviation (Evin, 1992; Juvigné et al., 1994a). The efficiency of the ^{14}C-dating method should be responsible for the remaining minor part of the deviation.

Three of the eighteen dates of the Laacher See Tephra (#1, #17, #18: i.e. 16.7 ± 8.7%) do not overlap the range of the weighed mean (10,895 ± 85 yr B.P.). Since the eruption lasted only a few days, it should be pointed out that, at the 1 sigma level, 8 of the 18 dates of the LST (#1, #2, #5, #6, #8, #13, #17, #18: i.e. 44.4 ± 11.7%) do not include the precise weighed mean (10,895 yr B.P.). Only 5 dates (#1, #13, #16, #17, #18: i.e. 27.7 ± 10.5%) should be rejected by accepting the median (10,955 yr B.P.) as the age of the LST. In short, the different percentages of unreliable dates depend on the severity of the rejection criteria; they are in ascending order: 16.7%, 27.7% and 44.4%. Hence it seems reasonable to accept that about 30% of dates should be rejected in any series corresponding to a very short term geological event (up to a few years).

2. Estimation of the rate of migration for a few plant species throughout the French Massif Central

In the French Massif Central, peat-bogs have been investigated intensively for the past decades by palynologists and tephrostratigraphers. Tephro-, and/or palyno-, chronostratigraphic models of the postglacial period have been published (Beaulieu et al., 1987; Beaulieu et al., 1988; Juvigné et al., 1988; Juvigné, 1991, 1993). In all of them, pollen features are supposed to be slightly diachronic time markers. The following time ranges for migration of tree species in the French Massif Central have been clearly pointed out: 200 yrs for *Fagus* (Pons et al., 1988) and 600 yrs for *Abies* (Guenet, 1993).

Sets of ^{14}C dates were collected for the following typical pollen features in pollen diagrammes of the French Massif Central: (i) the Late Dryas peak of *Artemisia* curve corresponding with a low of *Betula* curve (11 dates from 12,850 ± 650 to 9,050 ± 170 yr B.P.); (ii) the beginning of the continuous curves (2% level; Juvigné et al., 1988) for *Quercus* (14 dates from 12,095 ± 720 to 8,340 ± 150 yr B.P.), *Ulmus* (15 dates from 10,500 ± 160 to 7,020 ± 300 yr B.P.), *Tilia* (18 dates from 10,110 ± 375 to 6,860 ± 250 yr B.P.) and *Fraxinus* (13 dates from 9,445 ± 600 to 6,075 ± 300 yr B.P.); (iii) the middle of the steeply rising curves for *Corylus* (16 dates from 10,970 ± 775 to 8,020 ± 280 yr B.P.), *Fagus* (20 dates from 6,670 ± 110 to 4,010 ± 170 yr B.P.) *and Abies* (12 dates from 6,520 ± 245 to 3,415 ± 505 yr B.P.). Since the characteristics of samples, responsible for deviations of ^{14}C dates for the Laacher See Tephra, should give similar deviations by dating identical material in relation with pollen features, the time ranges obtained for pollen features can be compared with the one for the Laacher See Tephra (Fig. 1A-B).

Figure 1A-B shows that pollen features are biostratigraphical tools corresponding to various time ranges. The individual durations depend on the percentage of rejected ^{14}C dates. By rejecting the extreme values of each series for up to 30% of all data, the time ranges of each pollen feature to be recorded throughout the area vary from 2 to 15 centuries (Tab. 1).

The varying time ranges obtained for the individual plant species may be linked with the various dynamics of the migration of the relevant plants. For individual plants, there should also be relationships between the duration of the plant migration and: (i) the combination of climatic factors triggering the development/regression of the plant species; (ii) various degrees of relief (the altitude of the investigated area is between 850 m and 1500 m a.s.l.).

3. Palyno, tephro, chronostratigraphic model

The model represented in Figure 2. In difference to previous models (Beaulieu et al., 1987; Beaulieu et al., 1988; Juvigné et al., 1988; Juvigné, 1991; Juvigné, 1993), this one shows that a determined pollen feature is diachronic enough to occupy various stratigraphic positions in comparison with a tephra bed which is a sharp time marker.

The Montcineyre, Montchal, Pavin tephra group should always occur: (i) above the beginning of the continuous curve for *Fraxinus;* (ii) below the steeply rising curve for *Fagus* and *Abies.* Nevertheless there is one locality (Graspet, in Reille et al., 1985) where the continuous curve of *Fraxinus* begins above the Pavin Tephra. This indicates that the diachronism of that pollen feature should be larger than estimated at the 30% level of rejected data (see above).

Palynozones are usually used as chronozones in the French Massif Central (e.g. Beaulieu et al., 1982, 1984, 1985; Reille et al., 1985), but the same underchronozone may occur below or above the Pavin Tephra (in Reille et al., 1985, p. 213, Table 1). This is unacceptable and may be explained by subjectivity of palynozonation.

The La Vache-Lassolas Tephra and the trachytic sheets of the Chaîne des Puys should occur: (i) above the beginning of the continuous curve (2% level; Juvigné et al., 1988) for *Ulmus* and the steeply rising curve for *Corylus;* (ii) below the beginning of the continuous curve (2% level) for *Tilia* and *Fraxinus.*

At the sole locality where it was found, the Puy de Dôme Tephra is effectively present below the steeply rising curve for *Corylus.*

The stratigraphical relationship between the Godivelle Tephra 4 and the Late Dryas peak of *Artemisia* curve (low of *Betula)* curve is more delicate. The age of the transition Allerød to Late Dryas can be discussed by considering the series of dates concerning: (i) the Late Dryas peak of *Artemisia* curve (low of *Betula* curve); (ii) T5 and T4 which are obviously comprised in the upper part of the Allerød pollen zone in various peat-bogs (Bastin et al., 1990). Two different compromises could be proposed.

(i) On the one hand, according to the period corresponding to the peak of *Artemisia,* the cooling phase of the Late Dryas should have begun shortly prior to 10,400 yrs B.P. On the other hand, the most likely ^{14}C age for T4 is between 10,340 and 10,240 yrs B.P. There is a controversial overlapping of both periods of at least 150 years. Any chronologic compromise within that time span would also give a limit that is a few centuries more recent than the ^{14}C ages proposed by other authors e.g.: (i) Mangerud et al. (1974), 11,000 yrs B.P.; (ii) Gilot et al. (1969), 10,850 yrs B.P.; (iii) Beaulieu et al. (1982), 10,700 yrs B.P.

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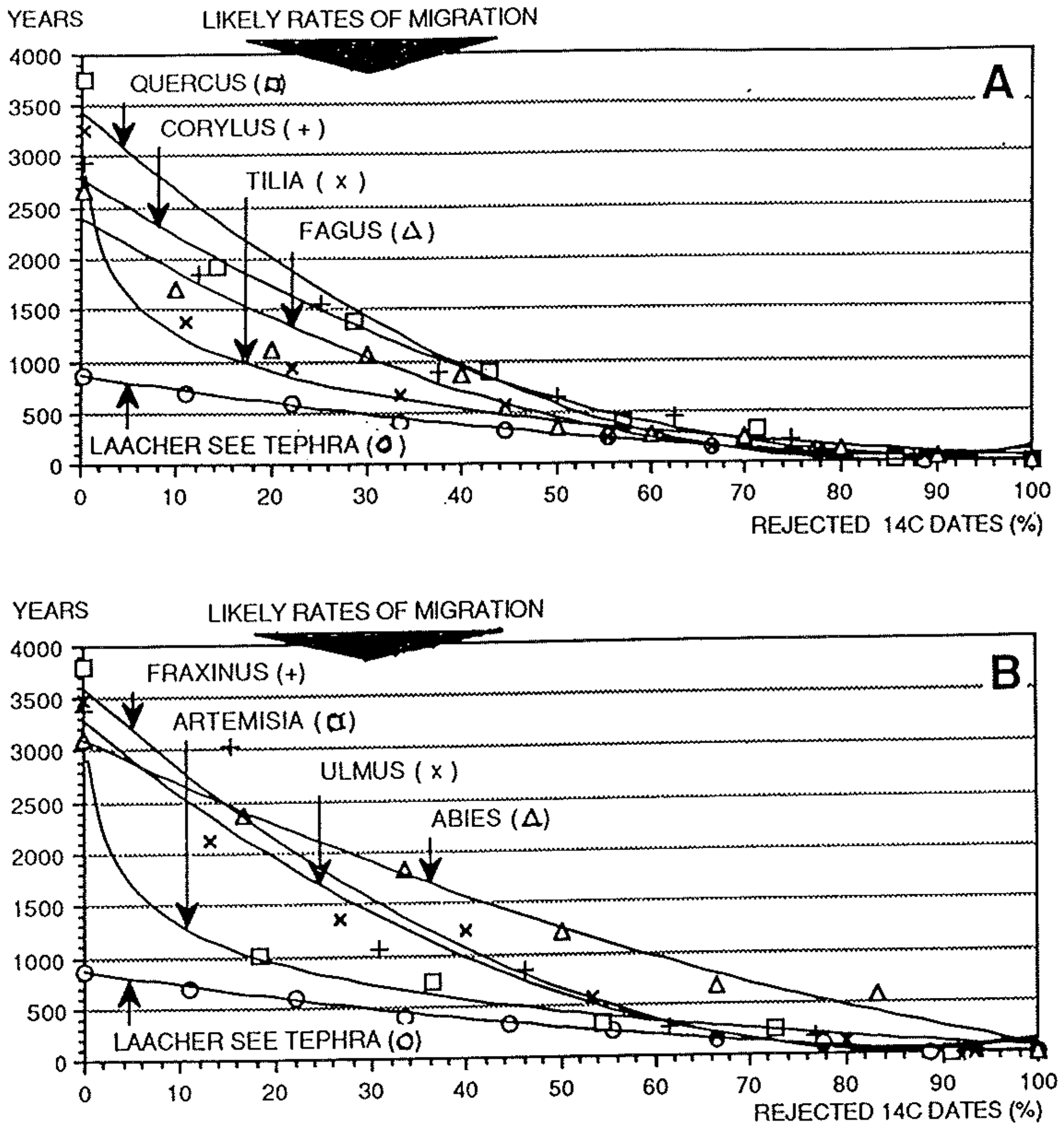

Figure 1 Estimation of diachronism of typical pollen features of the French Massif Central. Chosen pollen features: *Fagus, Abies, Corylus:* middle of the steeply rising curves; *Fraxinus, Tilia, Ulmus, Quercus:* beginning of the continuous curves (2% level; Juvigné *et al.*, 1988); *Artemisia:* Late Dryas peak of curve corresponding with a low of *Betula* curve.
For details on construction of both figures, see Juvigné *et al.* (1994a-b).

POLLEN FEATURE [FIG. 1 A-B]	DURATION OF MIGRATION [YEARS]	PERIOD OF MIGRATION [Yr B.P.]
FAGUS	600	4800 TO 4200
ABIES	1500	5500 TO 4000
FRAXINUS	700	7000 TO 6300
TILIA	200	7200 TO 7000
ULMUS	900	9600 TO 8700
CORYLUS	700	9700 TO 9000
QUERCUS	900	10200 TO 9300
ARTEMISIA	250	10400 TO 10150

Table 1 Periods of recording of 8 typical pollen features in pollen diagrams of a 100x100 km large area of the French Massif Central [Chaîne des Puys (N) to Aubrac (S), and Artense (W) to Monts du Forez (E)].

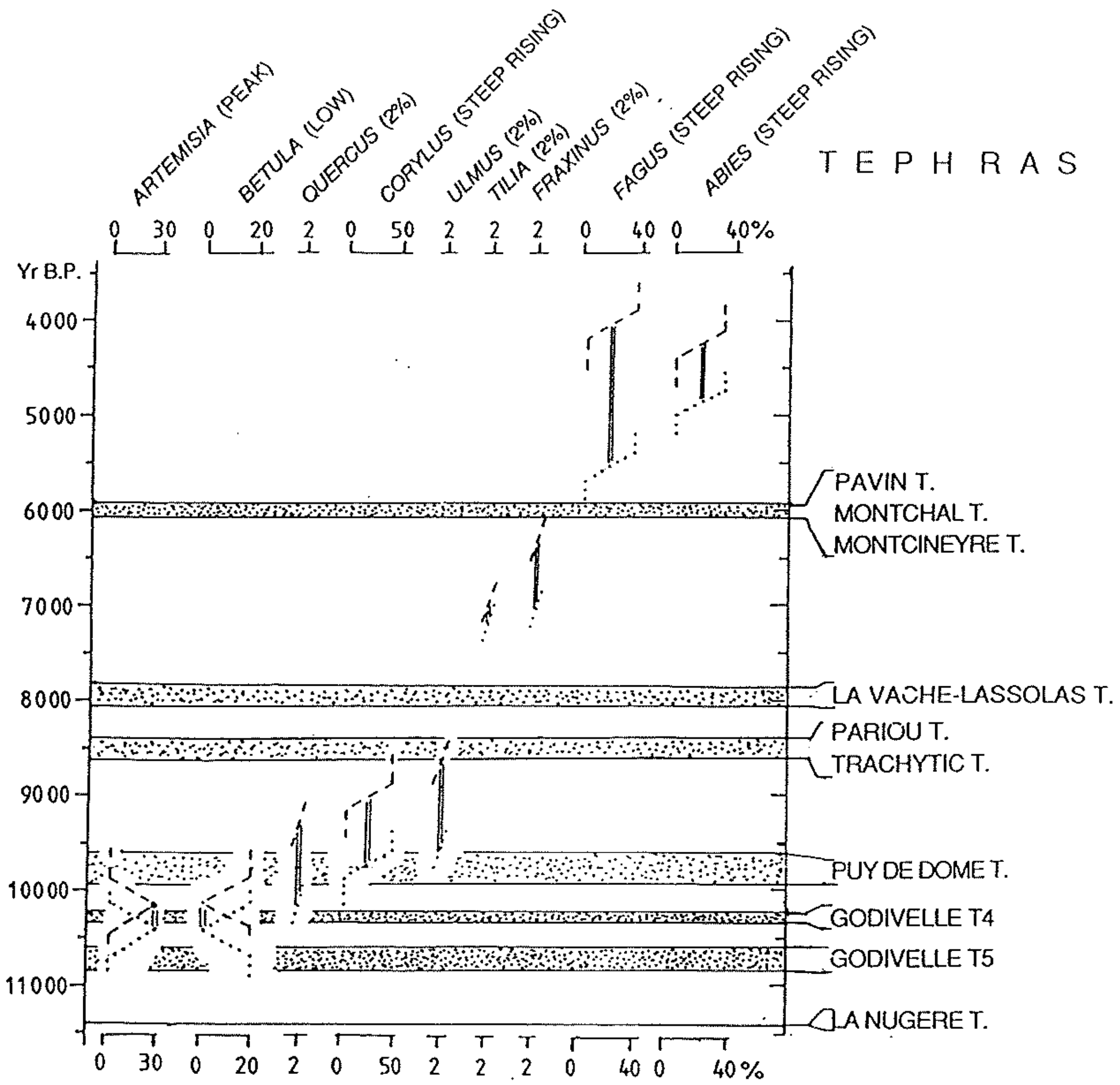

Figure 2 Palyno-, tephro-, chronostratigraphic model for the post-glacial time in the French Massif Central according to results obtained in peat-bogs.
Explanation.- The pollen features are defined in legend of Figure 1. The diachronism of individual pollen features are represented by a double line according to the values of Table 1; the dotted lines represent the likely oldest chronostratigraphic position of the pollen features, and the broken lines the likely youngest ones. The averaged time ranges corresponding to the duration of the steep rising curves for *Corylus*, *Fagus* and *Abies* are about 500 years (Juvigné *et al.*, 1988). The strippled lanes represent the time ranges including the relevant ages of the various tephras.