Multi-Pluridisciplinary approach of the evolution of the agro-pastural activities in the surroundings of the ” narse d’Espinasse ” (French Massif Central, Puy de Dôme).

Yannick Miras, Fatima Laggoun-Défarge, P. Guenet, H. Richard

Multi-disciplinary approach to changes in agro-pastoral activities since the Sub-Boreal in the surroundings of the narse d'Espinasse (Puy de Dôme, French Massif Central)

Y. Miras[1] , F. Laggoun-Défarge[2], P. Guenet[3] and H. Richard[1]

(1) Laboratoire de Chrono-Ecologie, UMR 6565/CNRS, Université de Franche-Comté, 16 route de Gray, 25030 Besançon cedex, France
(2) Institut des Sciences de la Terre d'Orléans, UMR 6113/CNRS, Université d'Orléans, BP 6759, 45067 Orléans cedex 2, France
(3) EPLEA H. Queuille, route de l'
agriculture, 19160 Neuvic, France

Abstract
The "narse" or peat marsh of Espinasse (Saulzet-le-Froid district) situated in the southern part of the Chaîne des Puys has been the subject of a new pollen analysis concentrating on the anthropogenic impact on vegetation evolution since the Sub-Boreal. Human occupation of the surroundings of the narse is dated as early as the Neolithic, which is usual for the region. There is nevertheless an isolated record of *Fagopyrum* related to the Neolithic. This is a unique occurrence in the Massif Central. For successive periods and up to the recent past, a dynamic of various anthropization phases has been reconstructed. The combination of palynological data with archaeological and historical sources has for certain periods, mainly from the 11th to 13th centuries, provided new insights on the social and technical management of the territory. Furthermore, geochemical and micromorphological characterisation of sedimentary organic matter has led to the identification of erosive crises and silting which would have followed massive tree cutting in the region. On the local scale, the highly degraded organic matter at the top of the peat profile is the consequence of the current drainage of the marsh.

Keywords : Narse d'Espinasse - Massif Central - Human impact - Palynology - Organic matter - Agro-pastoral activities

Introduction

For the first time in the Auvergne, pollen analysis concentrating on the anthropogenic impact on vegetation evolution has been carried out. The pollen analysis of the Espinasse peat marsh or « narse » presented here attempts to go beyond the characterisation of human impacts on the environment in order to understand the different agro-pastoral dynamics succeeding each other in the region.

The Espinasse peat marsh (02º53'E, 45°38'N; 1160 m a.s.l.) is a circular depression 500 m wide, having a surface area of 21 ha. It is surrounded to the north by a volcanic structure, the Puy de l'Enfer, and located between the southern part of the Chaîne des Puys (Saulzet-le-Froid district, Puy de Dôme, France) and the northern part of the Monts Dore. The marsh occupies a former basaltic « maar », formed around 10550 B.P., about 70 m deep (Camus *1975*). It is currently occupied by many herbaceous mesotrophic to eutrophic species and small trees such as *Betula*, *Salix* and *Alnus* (Brunhes et al. *1990*).

The narse is situated in the montane belt (lower limit about 750 m a.s.l.) characterised by *Fagus sylvatica* and *Abies alba*. *Abies* is more developed in this northern part of the Monts Dore because of increased moisture. The hilly belt (up to 820 m a.s.l.) is mainly characterised by *Quercus petraea*.

In the past, this area has attracted the pioneers of pollen analysis in the French Massif Central

such as Lemée (*1942*) and Dubois et al. (*1945*). More recently, the narse d Espinasse has been the subject of a partial pollen analysis conducted as part of a multidisciplinary study (Juvigné et al. *1988*).

The narse d'Espinasse is a particularly suitable study site for the linkage between social and environmental changes. A high rate of sedimentation has provided a good record of the Sub-Boreal and Subatlantic. To show this, a clear multidisciplinary approach has been chosen. The association between pollen analysis and a thorough study of the organic matter (OM) represents a key issue for a better understanding of the marsh and its catchment. Several studies have shown that the proportion, together with the chemical and petrographic composition of OM in sediments, soils and peats, are parameters sensitive to environmental variations and can be used as tools to reconstitute recent and ancient ecosystems in natural and anthropogenic environments (Meyers and Lallier-Vergès *1999*; Bourdon et al. *2000*). So this research includes geochemical and micromorphological studies of organic matter, particularly interesting in identifying erosive crises, phases of silting and the evolution of local environmental conditions since the Sub-Boreal.

In addition, the comparison of palynological data with archaeological and historical sources gives knowledge of the social and technical management of the territory (Galop *1998*). For this, the archaeological context of the narse d'Espinasse has been reconstructed. Human occupation of the Saulzet-le-Froid district is known from the Gallo-Roman period onwards, in spite of the relatively high altitude of the area of around 1000 m. The only traces of former human occupation are the Menhir du Fohet, situated in the village of Aydat, initially dated to the end of the Late Neolithic, and the Neolithic habitation of the Puy d'Alou, which was used again during the Gallo-Roman period (Fig. 1). The archaeological knowledge of the surroundings of Saulzet-le-Froid is based on ground and air surveys and on several archaeological excavations under emergency rescue conditions. Two air survey campaigns led by the CERAA (Centre d'Etudes et de Recherches d'Archéologie Aérienne; Chapeau and Claval *1985*) located tracks of supposedly ancient roads, between the Puy de Montenart and Pontaval, at a fork in the southwest of the Puy de Montenart on the way to the Puy Baladou in the village of Vernet-Sainte-Marguerite. Dr. Lhéritier's remarks quoted by Jouannet and Provost (*1990*) hypothesise a route connecting Clermont-Ferrand to the Mont Dore where the Rajat temple would have been located, and also a route forking toward Besse-en-Chandesse. On the Puy de Montenart, this supposedly ancient road crosses the Mazets Gallo-Roman villa. In terms of later human occupations in the Espinasse region, next to the peat marsh, the Tourette hillock has all the characteristics of a feudal mound. Further to the south in the village of Vernet-Sainte-Marguerite, a medieval necropolis has been identified. Finally, on the west side of the Montcharlet mound (Aydat village), at the boundary with Saulzet-le-Froid, small quadrangular features, probably of anthropogenic origin, have been revealed by air surveys (Chapeau and Claval *1985*). They are traces of 'burons', temporary habitations used at least since the 13th century to shelter herdsmen during the summer months. It is clear that the archaeological knowledge of the area studied (in particular for the Neolithic and Protohistory) is highly fragmented since no research has been conducted since 1985.

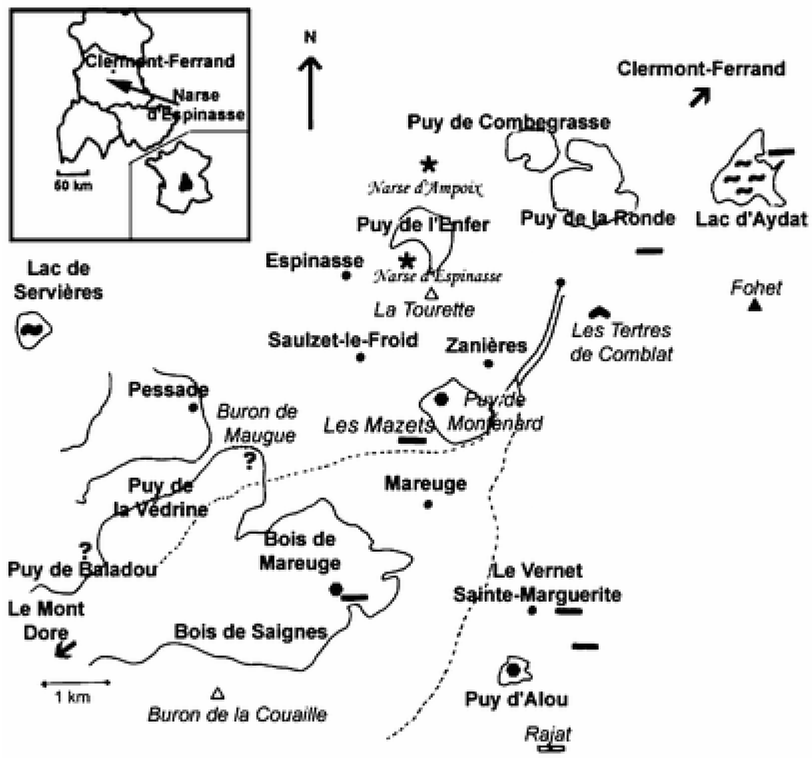

Fig. 1. The archaeological and historical context of the narse d'Espinasse surroundings (*5-pointed star*) palynological sites, (*filled circle*) town, (*filled triangle*) menhir, (*inverted v*) tumulus, (*filled hexagon*) neolithic or protohistoric settlement, (*black bar*) gallo-roman sites, (*white bar with dot*) gallo-roman temple, (*white triangle*) feudal hillock, (*?*) possible site for the ban of la Védrine, (*dotted line*) recognized supposedly antique roads, (*continuous line*) supposedly antique roads described by written sources

Methods

Pollen analysis

The core was taken in July 1995 with a 5-cm-diameter Russian corer. Coring was in the deepest part of the narse (Fig. 2), near borehole S2 made in 1987 (Juvigné et al. *1988*). The samples were taken every 5 cm to a depth of 100 cm, then every 10 cm to the base of the sequence (1049 cm). Pollen preparation followed standard methods using treatment with 10% HCl, 10% NaOH, HF, acetolysis and final mounting in glycerine. Possibly because of the high sedimentation rate, the pollen concentrations are very low. A minimum of 150 pollen grains was adopted for the poorest spectra (which represent 17% of all the spectra). For the others, a minimum of 300–350 pollen grains was preferred. Among 113 spectra, only 103 have been retained. The following levels were rejected as being too poor in pollen: 39, 179, 189, 379, 439, 449, 459, 469, 579 and 679 cm. For the main diagram (Fig. 3), the pollen sum includes all pollen of vascular plants excluding Cyperaceae, other local hydrophytes (*Equisetum*, *Typha*, *Nuphar*, *Myriophyllum*, *Menyanthes*, *Potamogeton*, *Sparganium*), Pteridophyta and *Sphagnum*. A simplified diagram based on a calculation sum including all pollen and spores is found in Fig. 4. The profiles are divided into local pollen assemblage zones (PAZ) defined by the most important local and extra-local taxa.

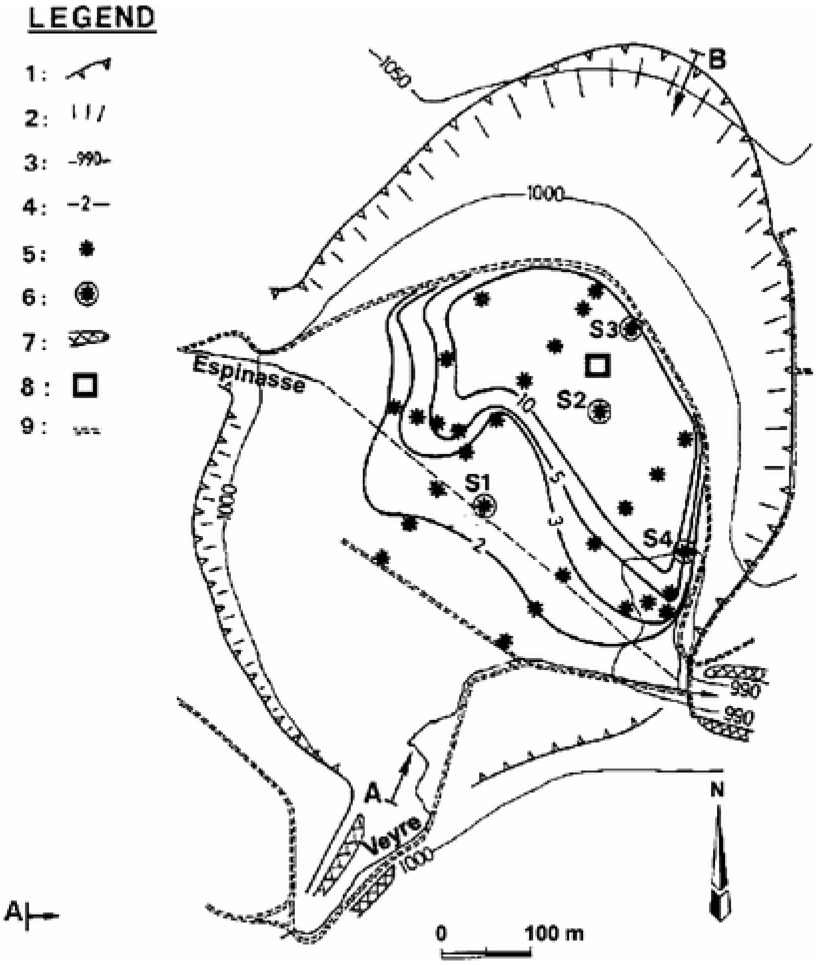

Fig. 2. The geomorphological map of the narse d Espinasse and the coring points (according to Juvigné et al. *1988*). Captions: 1 - angular convexity; 2 - edge of Richter denudation slope (Juvigné et al. *1988*); 3 - contour in meters; 4 - thickness of the peat in metres; 5 - boring points (Juvigné et al. *1988*); 6 - sample borings (Juvigné et al. *1988*); 7 - fluvial terraces; 8 - sample boring (Laggoun-Défarge et al. *1998*); 9 – walkways

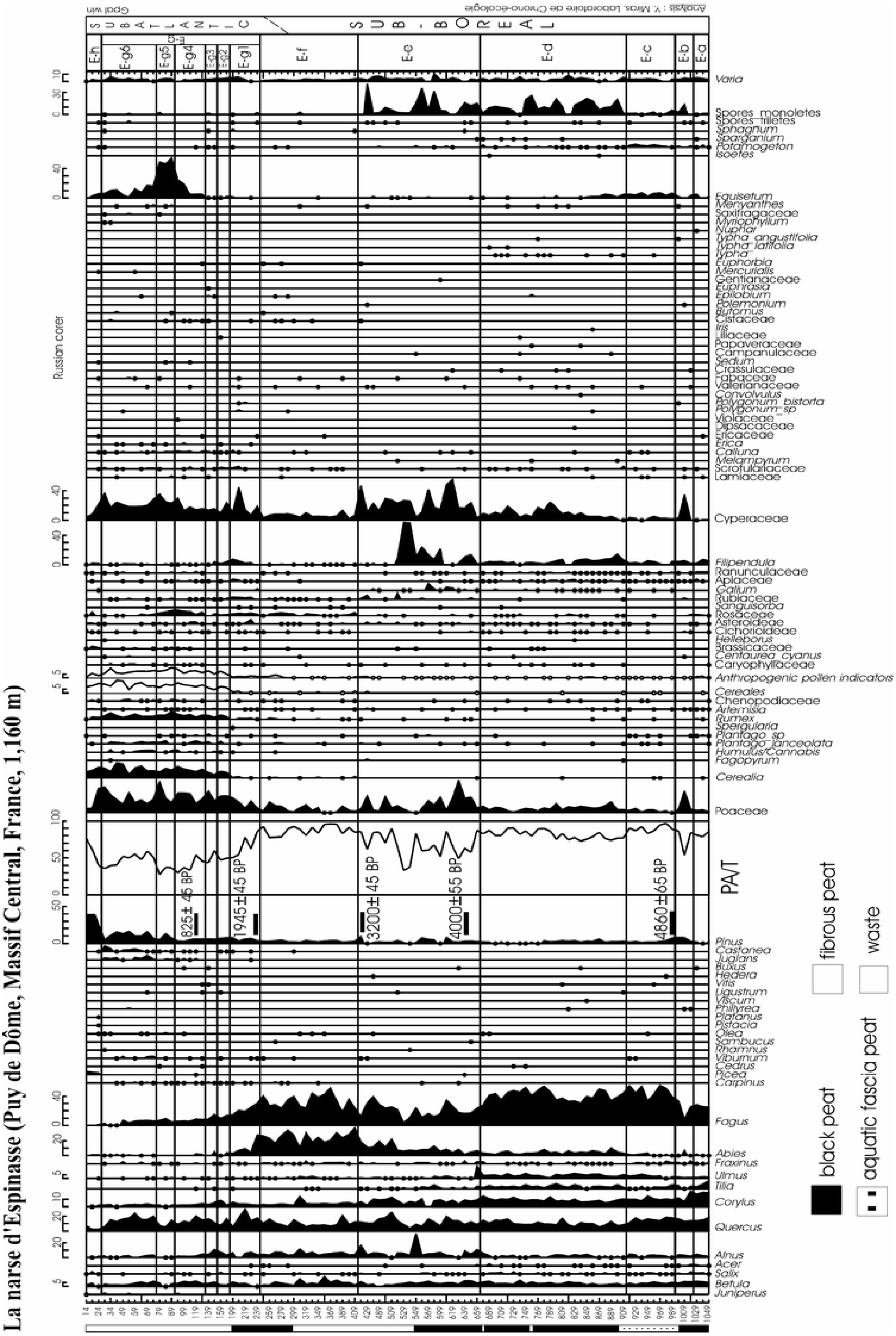

Fig. 3. Pollen diagram from the narse d'Espinasse (Massif Central, France)

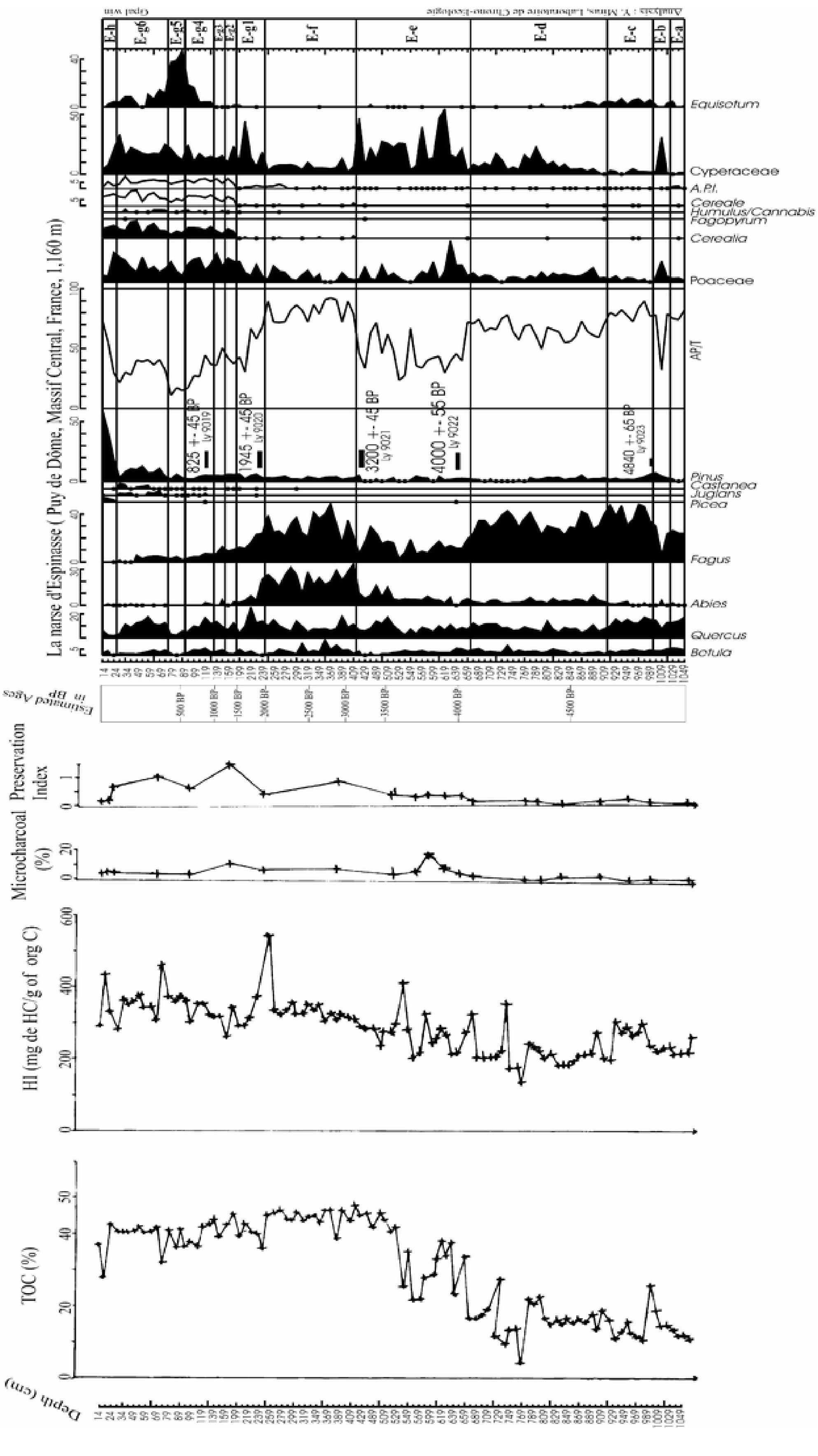

Fig. 4. Geomorphological and petrographical results correlated with a simplified version of the palynogram from the narse d'Espinasse

Radiometric data

Five conventional bulk-datings (Table 1) were made by the Centre de Datation par le Radiocarbone de l'Université C. Bernard (Lyon-I) and calibrated according to Dataset 1 (Stuiver and Reimer *1993*). Based on these 5 datings, and thanks to the DEP-AGE program (version 3.4., L-J. Maher), a chronological estimation for the entire sedimentary record is proposed. This estimation is based on an assessment of the sedimentation rate established from a linear interpolation of non-calibrated dates. The estimated ages are expressed in years B.P. (uncal) and compared with other accepted dates of similar palaeobotanical events (Guenet *1986*; Beaulieu et al. *1988*; Reille et al. *1992*; Table 2).

Table 1 Bulk ^{14}C data calibrated according to Stuiver and Reimer *1993*

Depth (cm)	Lab. code	Age (B.P.)	cal B.P. 2	B.C. / A.D.
118–122	Ly 9019	825 ± 45	885 (730) 668	A.D. 1065 (1220) 1282
236–240	Ly 9020	1945 ± 45	1991 (1884) 1818	42 B.C. (A.D. 66) 132
420–425	Ly 9021	3200 ± 45	3547 (3439,3429,3399) 3274	1598 (1490,1480,1450) 1325 B.C.
638–643	Ly 9022	4000 ± 55	4780 (4500,4490,4440) 4299	2830 (2551,2541,2491) 2349 B.C.
990–992	Ly 9023	4840 ± 65	5708 (5592) 5334	3758 (3643) 3384 B.C.

Table 2 Evaluation of radiometric data

Dates (uncal B.P.)	Botanical event	Comments
825 ± 45	Total disappearance of *Abies*	The same botanical event is dated to 680 ± 60 B.P. in Chambedaze in the Cézallier (Guenet *1986*).
	1st true peak in *Cannabis-Humulus*	A closest date 760 ± 50 B.P. is proposed for the start of hemp culture for the Lac Noir in Artense (Guenet *1986*)
1945 ± 45	Important regression of the beech-fir forest has already started	The forestry status of the Massif Central was greatly damaged by man between 2600 and 2200 B.P. (Beaulieu et al. *1988*).
	1st note of *Juglans*	The *Juglans*-line, if admitted, is nearer 2000 B.P. (Beug *1975*).
*3200 ± 45[1], *4000 ± 55		Interpretation of these dates is impossible as they do not correspond to any major botanical event but to variations in local taxa
4840 ± 65	*Fagus* about 30%	Similar rates of *Fagus* just before the optimum of the beech forest, are dated at 4780±80 B.P. in Vézolle, in the Chaîne des Puys (Michelin et al. *2001*)

[1]isolated date

Geochemical and micromorphological analysis of the organic matter

The organic geochemistry parameters were obtained by Rock-Eval pyrolysis which provides the Total Organic Carbon (TOC, %) and the Hydrogen Index (HI, mg HC/g organic C). These parameters depend on the lacustrine biological activity, input of organic detritus, and syn- or post-sedimentary processes of degradation of OM. The petrographic study (palynofacies) involved light microscopic examination, in transmitted and reflected light, of total OM after acid hydrolysis of carbonates and silicates. Smear slides of bulk sediments were also examined in transmitted light. Petrographic analyses were conducted for identification and quantification of organic compounds, and determination of their allochtonous (weathered from the catchment and/or windblown, including microcharcoals) or autochtonous (aquatic or subaquatic plants and phytoplankton) origin. A Preservation Index, reflecting the environmental conditions, was determined as the ratio of the relative proportion of well-preserved plant tissues to the sum of amorphous organic matter and structured plant tissues.

Results

The results of the pollen analysis (Fig. 3) are summarised in Table 3 and will be widely considered in the discussion. Variations in TOC, HI and the relative proportions of organic constituents through the core (Figs. 4, 5) allowed the identification of two relatively well-defined units separated by a transition phase.

The upper unit (15 – 519 cm) with a considerable accumulation of OM (40% TOC) of essentially terrestrial origin, was composed primarily of moss and Cyperaceae tissues. Except for the top of this unit where OM is highly amorphous, plant tissues were morphologically well preserved. The high Hydrogen values confirmed this preservation (HI between 350 and 400 mg HC/g TOC). The lower unit (between 759 and 1039 cm), in addition to OM from vascular vegetation, showed a contribution of amorphous OM, probably arising from phytoplankton, and a notable presence of diatoms. In this unit, OM was highly degraded and the TOC and HI values were relatively low. Between these two units (519–759 cm), TOC and HI values varied considerably. In addition, there were relatively significant quantities of carbonised remains from fires.

The lower part of the transitional organic sequence is probably evidence of the end of the lake filling, transforming itself during the Subatlantic into a marsh with an accumulation of paludicolous vegetation where the water level would have been minimal. The transition between these two sequences would correspond to a period of relative instability of the plant cover on the catchment, in particular marked by a decrease of *Fagus* pollen (Fig. 4). Locally, this is shown by the input of charcoal remains, probably from fires that were most likely anthropogenic. Finally, OM at the top of the sequence is highly degraded (96% TOC) and was almost certainly influenced by regular ground-clearing, grazing and drainage of the narse.

Table 3 Results of the pollen analysis

Depth (cm)	Chrono-Zones	Strati-graphy	PAZ	Age (uncal B.P.)	AP / T %	Regional pollen assemblage characteristics	Local pollen assemblage characteristics	Anthropogenic Pollen Indicators (API)
14 24	SUBATLANTIC	Fibrous peat	E-h		80 40	-peaks of *Picea*	-decrease in *Equisetum*, Cyperaceae	-end of the curves of *Castanea*, *Juglans* -decrease in Cerealia -peak in heliophytes (*Betula*)
29 74			E-g: E-g6		40 50	-end of representation of *Fagus* -return of *Quercus*		-record of *Fagopyrum* -continuous curves of *Castanea*, *Juglans*
79 94			E-g: E-g5		40 30	-decrease in *Quercus*	-peak of *Equisetum*	slight decrease in Cerealia and different ruderals
99 118 122 129			E-g: E-g4	825 ± 45 Ly9019	40 50	-extinction of *Abies* -low rates of *Fagus*	-start of *Equisetum* -good representation of Poaceae	-important and regular representation of Cerealia and other API -regular occurrences of *Castanea*, *Juglans*
139 149			E-g: E-g3		60 50	-increase in *Fagus* and *Abies*		-slight decrease in Cerealia and other API
159 189			E-g: E-g2		60 60	-low rates of *Fagus* and *Abies*		-increase in the API mainly *Plantago lanceolata*… -1st curve of Cerealia
199 236 239		Black peat	E-g: E-g1	1945 ± 45 Ly9020	60 90	-strong reduction in *Fagus*, *Abies*	-increase in Cyperaceae	-increase in apophytes mainly *Rumex*, *Artemisia*, Rubiaceae -regular occurrences of Cerealia, *Castanea* -1st note of *Juglans*
249 409	SUB-BOREAL		E-f		80 90	-decreases in *Fagus*, *Abies* -optimum representation of the beech-fir forest	-low values of Cyperaceae	-curve of the API -peak in Cerealia -1st note of *Cannabis-Humulus*
419 425 420 638 643 659		Fibrous Peat Black peat	E-e	3200 ± 45 Ly9021 4000 ± 55 Ly9022	90 70	-end of the curves of *Ulmus*, *Tilia*	-high rates of Cyperaceae and monolete spores -increase in Cyperaceae	-2nd record of *Fagopyrum* - record of Cerealia, ruderals like *Plantago lanceolata*
669 799 869 889 909			E-d		90 65 70 85	-3rd decrease in *Fagus* -2nd decrease in *Fagus*	-end of curve of *Equisetum* -extension of Poaceae, monolete spores	-record of Cerealia, ruderals -1st record of *Fagopyrum*
919 949 969 992		Aquatic fascia peat	E-c	4840 ± 65 Ly9023	95 95	-1st decrease in *Fagus* -curve of *Abies*	-decrease in *Potamogeton*, Cyperaceae	-2 successive records of Cerealia -increase in ruderals
999 1019		Black peat	E-b		90 70	-decrease in *Fagus*	-increase in monolete spores, Poaceae, Cyperaceae	-apophytes : Rubiaceae, Cichorioideae, *Centaurea cyanus*
1029 1049			E-a		85 90	-curve of *Fagus* -regression of *Tilia*	-increase of *Equisetum* -forbs community	-different ruderals -record of Cerealia

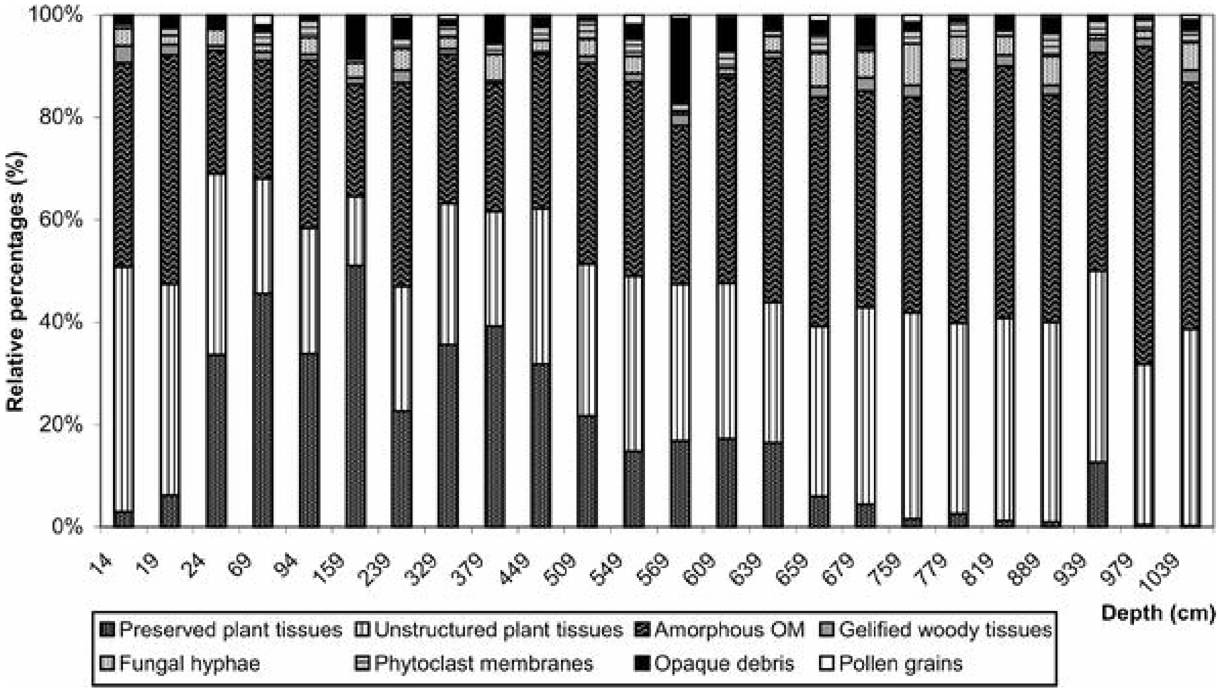

Fig. 5. Relative proportions of organic constituents from the palynofacies study of the narse d'Espinasse

Discussion

Comparison of our pollen analysis of the narse d'Espinasse (Figs. 3, 4) with previous research is impossible, at least in terms of the oldest work (Lemée *1942*; Dubois et al. *1945*). This is because early work was incomplete and based primarily on the recognition of tree taxa; it provided an image of the Atlantic period, not shown in our diagram, and classically revealed the development of a mixed oak forest characteristic of this period in the Massif Central (Beaulieu et al. *1988*). A more recent published diagram (Juvigné et al. *1988*) is based on the core S2 situated close to our coring site, but similarly the two diagrams cannot be compared. Firstly, the earlier work describes the end of the Boreal, the Atlantic and the beginning of the Sub-Boreal periods, except the last not described in our study. Secondly, even for the early Sub-Boreal, comparison is impossible because the earlier diagram suffers from shortcomings such as the non-identification of tree pollen such as *Abies*.

Interpretation of pollen data

Neolithic: E-a / E-d; ca. 5000 – 4000 B.P.

At the base of the diagram [E-a], a beech forest was already present around the site, marking the start of the sedimentary record during the Sub-Boreal. The number of beech trees largely explains an AP/T ratio oscillating between 70 and 80%, which indicates closed forests for the Massif Central. The regular occurrence of *Abies* shows a better representation of this taxon compared to the neighbouring site of Ampoix. There, *Abies* was unsuccessful at the beginning of the Sub-Boreal (Beaulieu and Goeury *1987*). Its subsequent development remained mediocre, while at Espinasse, a beech and fir forest became established later. According to Lucquet (*1926*), fir did not expand well on the eastern side of the Mont Dore chain because of a lack of moisture, although at the same time on both sites, taxa characteristic of mixed oak forest (e.g. *Fraxinus*, *Acer*) thrived.

Human occupation of the surroundings of the narse d'Espinasse is shown at the base of the diagram by a record of Cerealia and by regular occurrences of different ruderals (*Artemisia*, *Rumex*, Caryophyllaceae, *Plantago* sp., *Plantago lanceolata*, Asteroideae, Chenopodiaceae). A dispersion of these taxa from distant lowlands cannot be totally excluded, but is unlikely because the narse d'Espinasse is situated in the heart of a vast plateau.

The remarkable vigour of Cyperaceae and Poaceae frequencies [E-b], showing the development of a sedge community, leads to a considerable rate of decrease in the principal arboreal taxa (*Fagus*, *Quercus*). The large and abrupt decrease of the AP/T ratio cannot be interpreted as a sign of landscape opening of any kind. According to Beaulieu et al. (*1985*), « *everything is going on as if the presence of a sheet of Cyperaceae on the site introduced an intermediary stage, favouring the differential destruction of less solid pollen types* ». The comparison of the two pollen diagrams does not show any relevant variations in the representation of the main taxa. It confirms this filtering and destructive effect of the Cyperaceae.

The frequencies of *Fagus* subsequently tended towards normal levels, while locally Cyperaceae declined. At the same time, the continuous *Abies* curve begins. Fir development seems slower and less prominent than that of beech. In the middle of the zone [E-c], a first decrease in values of *Fagus* coincides with two consecutive records of Cerealia and with an increase and a diversification of the ruderals group, also *Plantago lanceolata* is noted for the first time. Later, two other decreases in the *Fagus* curve are observed [E-d] while the presence of apophytes is both sustained and relatively diversified (*Plantago lanceolata*, *Rumex*, *Galium*, Cichorioideae, Asteroideae, Rosaceae) and the representation of Poaceae increases, as does that of the taxa of the forbs community (*Filipendula*, Cyperaceae). On the other hand, the indications of cereal cultivation are sparse with the occurrence simply of Cerealia. At the same time as the reduction in beech frequencies occurs *Fagopyrum* is identified, but without any clear evidence of cultivation.

Final Neolithic – Bronze Age and Iron Age: E-e / E-f; ca. 4000 – 2000 B.P.

At the transition of the zones [E-d] / [E-e], just before 4000 ± 55 B.P., a noticeable decrease in *Fagus* is followed by an occurrence of Cerealia pollen, a double record of *Plantago lanceolata* and regular occurrences of various other apophytes such as *Rumex* and *Artemisia*. These observations constitute only slight evidence of a human impact on vegetation, but should be taken into consideration. In fact just a little later, there is a change in deposit conditions, which could be the consequence of human activity within the drainage basin. It is demonstrated by the spread of Cyperaceae and Poaceae, and an expansion in the forb community. This considerable increase in Cyperaceae frequencies makes it difficult to interpret the rest of the zone [E-e] because of poor preservation of the pollen. At any rate, between 479 and 419 cm, the spectra contained too little pollen to be useful. This also explains the contemporaneous low rates of *Fagus*.

After 3200 ± 45 B.P., a return to a beech presence of more than 50% [E-f] occurred and *Abies* representation reached a maximum while that of Cyperaceae was negligible. This maximum in *Abies* is more due to an optimal pollen record (minimum of Cyperaceae) than any expansion linked to middle Bronze Age climatic degradation. The first peaks in Cerealia do not necessarily indicate an increased human impact but rather better pollen representation due to low Cyperaceae counts.

At the end of the pollen zone [E-f], linked to La Tène, a clearing of beech-fir forest is responsible for a decrease in the AP/T ratio. *Cannabis-Humulus* is recorded for the first time.

The Roman Era and the Early Middle Ages: E-g1 / E-g2 / E-g3; ca. 2000 – 1000 B.P.
Around the La Tène/Gallo-Roman transition (about 1945 ± 45 B.P.), which coincides approximately with the appearance of *Juglans* (it confirms the « *Juglans*-line »; Beug *1975*), man interrupted the natural dynamics of the vegetation [E-g1]. Thus, pollen frequencies of *Fagus* and *Abies* decrease considerably to the benefit of *Quercus*.

The practice of agriculture is indicated by high counts of various ruderals and by high frequencies of Poaceae, even if a part of this vigour is from new development of the marsh. Also, the continuous curves of Cerealia [E-g2] and apophytes are the first evidence for a mixed agro-pastoral economy. The post Gallo-Roman period is therefore not marked by a decline in human impact. The first regular occurrences of *Cannabis-Humulus* and *Castanea* appear somewhat later. A decrease in Cerealia, Poaceae and apophytes suggests a slight decline in agriculture [E-g3].

Lower Middle Ages to the present: E-g4/E-g5/E-h; ca. 1000 B.P. – the modern period
The total extinction of fir and the almost similar fate of beech is dated to 825 ± 45 B.P. [E-g4], which reveals the important rise in deforestation. The very low AP/T ratio (around 10%) represents an open landscape. All the anthropogenic pollen indicators have increased showing the development of a diversified cultural landscape. These episodes of intense deforestation probably caused a modification of the peat marsh dynamic by an increase in silting. It is reflected by a reactivation of the aquatic environment demonstrated by the vigour of *Equisetum*, *Menyanthes trifoliata* and *Potamogeton* as well as diatoms at the level of 94 cm [E-g5]. The maximum development of *Equisetum*, estimated at 530 B.P. can explain the slight decrease of the frequencies of cereals whose under-representation is well known. These variations cannot be linked to any agricultural decline, especially as cereal rates increased after the end of this *Equisetum* phase.

The regular occurrences and the continuous curves of *Juglans* and *Castanea* [E-g6] reveal these two trees were in fact cultivated. This diversified agriculture also included the planting of buckwheat since *Fagopyrum* is again present. The pioneer role of pine (Daget *1979*) and the decrease in Poaceae frequencies reveal a modern phase of agricultural decline. The appearance of *Picea* pollen reflects modern tree replanting [E-h].

A conceptual model of the development of the agro-pastoral activities
The multi-disciplinary approach adopted, correlating palynological, archaeological, historical, geochemical, sedimentological and micromorphological data (Figs. 3, 4, 5), has enabled the construction of a conceptual model of the development of the agro-pastoral activities (Fig. 6).

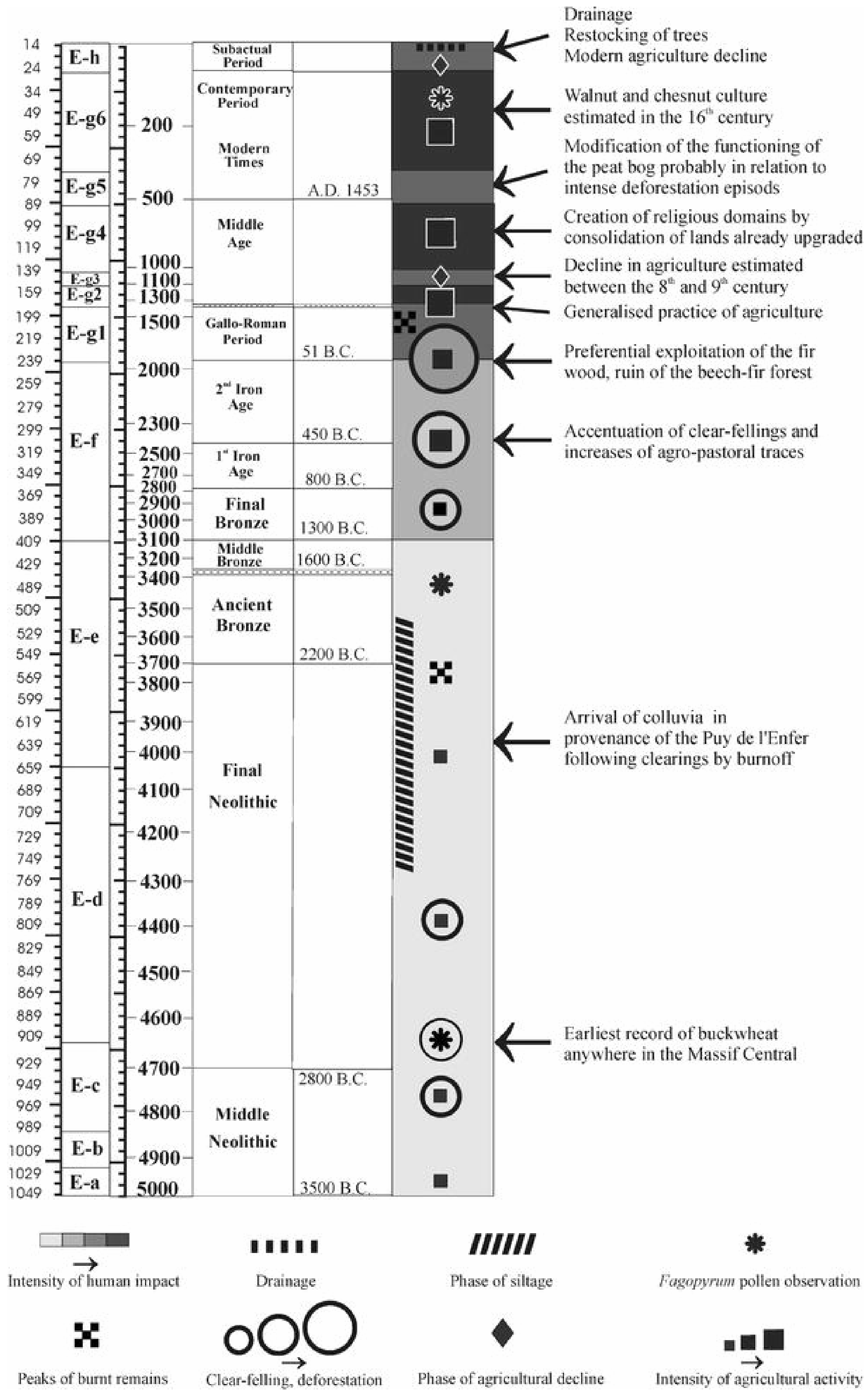

Fig 6. A conceptual model of development of agro-pastoral activities

First traces of human occupation as early as the Neolithic: E-a / E-b; 3500 B.C.
Human occupation of the surroundings of the narse d'Espinasse [E-a] took place most probably during the Neolithic, perhaps in the middle Neolithic. In any case, it was later than at the neighbouring site, the narse d'Ampoix, where anthropogenic pollen indicators appeared during the ancient Neolithic around 6500 B.P., making it the oldest anthropization trace in the entire Massif Central (Beaulieu et al. *1988*; Miras et al. *in press*). This initial human occupation is comparable with that revealed by pollen analysis of the Vézolle site situated to the north (Michelin et al. *2001*). In the Atlantic/Sub-Boreal transition around 4710 ± 80 B.P., observations of *Secale* are consistent with small forest clearing. These observations of *Secale* cannot be considered as the start of rye cultivation in the Chaîne des Puys. In this period rye expanded as a weed in cultivated fields. It has only achieved its status as a cultivated plant since the Roman period (Behre *1992*).

A wave of prehistoric clearance: E-c / E-d / E-e; 3500 B.C. – 800 B.C.
At the end of the middle Neolithic, there are slight hints of the clearance of beech but no expansion in Poaceae. Instead, pollen indicators of agricultural activity increase slightly. This attempt to win new ground was more marked during the late Neolithic in the following zone [E-d]. This human activity seemed to be more devoted to cattle breeding than cereal cultivation. In fact, in modern research on pollen assemblages, the group of taxa that increased includes mainly those generally associated with mowing and grazing (Gaillard et al. *1994*; Hjelle *1999*). Cultivated fields were not very extensive around the peat marsh. Despite this, the record of *Fagopyrum* is the oldest observation of buckwheat in the entire Massif Central. It is estimated as being from the beginning of the final Neolithic. However, this is a single observation that should be treated with caution and the possibility of contamination should be taken into account in any interpretation. These signals in the pollen record of human activity during the Neolithic are in contrast to the rarity of sites known from archaeological surveys in this area.

Between 759 and 519 cm, geochemical and sedimentological studies indicate a zone of considerable disturbance in the parameters examined. The high variation of TOC can be explained by a 'dilution' of organic matter in the sediment through the influx of colluvium. Between 569 and 519 cm, the drop in the HI can be explained by an increase of terrestrial organic matter over aquatic OM. These geochemical indices would correspond to silting between 759 and 519 cm, originating from the Puy de l'Enfer, and which could have resulted from clearance that spanned a period until the middle Bronze Age. Waste at the 685 and 760 cm levels also supports the possibility of erosive crises resulting from clearings. The micromorphological studies reveal a palynofacies very rich in charcoal remains (Fig. 4), attesting that clearance by burning is probable.

In summary, an increase in clearance seems to be evident from the Neolithic-Bronze Age transition. Pollen indicators of crops are rare except for a new record of *Fagopyrum* estimated to be from the middle Bronze Age. Again, the breeding supremacy is probable since many apophytes of trampled areas are recorded (Asteroideae, Rosaceae, Rubiaceae). Moreover, the pollen signal from the surroundings is diluted and corresponds to a large source area because of the large surface area of the narse. In such a case, the pollen influx from small cultivated areas close to the settlements and scattered among the grazed fields and forest would be very low.

Iron Age, Roman conquest and Early Middle Ages: E-f / E-g1–3; 3500 B.C. – 9th century A.D. Around the La Tène-Gallo-Roman transition, deforestation [E-g1] is accompanied by intensified agricultural practices. This deforestation largely involved fir trees. This preferential search for fir is explained by its mechanical and storage qualities, making it a good building material. From about 159 cm, there is a new charcoal phase in the palynofacies that may not be related to tree clearance by burning in view of the already strongly decreased AP/T ratio. This charcoal phase can be associated with burning for land improvement. Furthermore, a mixed agro-pastoral economy seems to be beginning. The post Gallo-Roman period is therefore not marked by a decline in anthropization [E-g2]. Historical data, once again very incomplete and old, relates to the late human occupation until the 5th century of the Gallo-Roman villa at Puy de Montenart (Lhéritier*1911*).

A slight decline in agriculture [E-g3] seems to have occurred between the 8th and the 9th century A.D. It is the first time such a decline has been identified in the Chaîne des Puys, where the idea of a continuous culture of cereals since the Gallo-Roman period until the 1960s is commonly accepted (Michelin *1995*).

From feudal management of local lands to the monarchical politics of consolidation of lands (Lower Middle Ages): E-g4; 11th – 13th century A.D.

The Middle Ages, particularly the 11th – 13th century, were evidently a period of deforestation and crop planting. At the beginning of the 13th century, deforestation was virtually complete in this area. When the Abbey of Saint-André was built in these highlands, it was difficult to find wood for its monks and personnel as well as for its clergymen (Fournier and Fournier *1983*). In the second half of the 12th century, the order of Prémontrés de Saint-André de Clermont acquired La Védrine, where they erected a building called the ‘Grange de la Védrine’ in the village of Saulzet-le-Froid. At the end of the 13th century, the domain of La Védrine was fully established.

Their principal economic activity was the raising of farm animals but crops were also cultivated, as the high frequencies of cereals demonstrate. Also, most if not all descriptions of farmland in the 13th century record refer to cultivated land and fields (Fournier and Fournier *1983*). According to the same authors, the transfer of control from clerics to laymen lords transformed the ways of rural life. However, and pollen analysis agrees with the historical data, the monks did not settle in unoccupied territories. They took over a deep-seated organisation that had existed for many years. It was not through clearance that clerics managed to create domains, but through the consolidation of lands that were already well managed.

The name of La Védrine, from the Latin *vitrina* meaning stained-glass window, suggested to these authors the existence of a glass-making workshop, an activity consuming vast quantities of wood. The authors therefore consider that *the forestry cover was still of some importance at the beginning of the first millennium*, something not really confirmed by pollen analysis as the beech and fir counts decreased considerably and very rapidly. On the other hand, the more impoverished counts of arboreal taxa just before 825 ± 45 B.P. indicate strong, regular and specialised forestry practices. Historical archives reveal that during this period, commercial exchanges between towns were rapidly expanding and avid consumers of wood were increasing. On this side of the Mont Dore, however, forestry was facilitated by roads leading towards Saint-Amand-Tallende or Champeix, or the plains of Clermont and Issoire.

According to the description of farmlands, which show that woodlands were replaced by large tracts of grazing land, husbandry was the main economic activity. The expansion of Poaceae in our diagram suggests the extent of grasslands. The frequencies are too high to assign to a purely local development (e.g. *Phragmites*), an idea supported by comparison with modern pollen assemblages found from the Mont Dore area (Guenet *1986*). However the expansion of broom (*Genista*) and heather moors, as discussed primarily by the Chaufayet farmland documents which distinguish heather from grasslands and which concern the domain on the south side of La Védrine, is not shown by our pollen analysis or by that from the neighbouring site of Ampoix (Beaulieu and Goeury *1987*). However, *these lands seem to have occupied a non-negligible place in the landscape and the economy of the mountain* (Fournier and Fournier *1983*). According to these authors, these moors suggested a poorly balanced pastoral economy. The pollen analysis in this region did not reveal any findings to suggest this. Even if broom is under-represented, development of *Calluna* or other Ericaceae would have appeared more clearly than was the case.

Evidence of stability of the agro-pastoral economy despite social and political upheaval: E-g5; 14th – 15th century A.D.

The episodes of intense deforestation probably caused an increase in silting. Colluvium accumulating in the outlet was responsible for a rise in the water table. This modification of the peat marsh dynamic is estimated to have taken place at 530 B.P.

There are no clear hints of the decrease in agricultural expansion at the end of the Middle Ages in the pollen record. In the Auvergne, however, the period of general crisis due to the Black Death and the Hundred Years War was, according to historical sources, marked by a decline in population leaving considerable land available (Charbonnier *1984*). According to the archives of Saint-André Abbey, the barn of La Védrine was in total ruin in 1408. Also, many villages were left abandoned, which was the case for the village of Aurières at the end of the 14th century (Charbonnier *1968*). In accordance with historical sources (Charbonnier *1984*), abandoned spaces multiplied to the detriment of various forms of arable territory. The author adds that *the mountains have come forth*. This is certainly not shown by pollen analysis from the narse d'Espinasse. In fact, no recovery by the pioneer taxa (*Betula*, *Pinus*) was noted, nor was there an increase in arboreal taxa such as *Fagus* or *Quercus*. Oak even reached its lowest frequencies in the entire diagram. It is nevertheless true that this period did not last very long in the Auvergne, since the English left the province in 1392.

From the agricultural golden age to the modern decline: E-g6 / E-h; 16th century – the modern period

The maximum in the culture of *Juglans* and *Castanea* dates from the 16th century [E-g6]. At this time, *Fagopyrum* was also cultivated in the surroundings of the narse d'Espinasse. The buckwheat fields could not have been far from the peat marsh in spite of the altitude. Guenet (*1986*) discussed buckwheat having been cultivated only some decades ago at a distance of 1000 m from the Chambedaze peat marsh in the Cézallier, at an altitude of 1180 m, for the purpose of making pancakes during the summer.

Due to the absence of radiocarbon datings for the rest of the zone, it is difficult to continue interpreting pollen data in relation to historical facts. Nevertheless, the maximum in forestry decline and the maximum expansion of *Juglans* and *Castanea* should correspond to the optimum in rural demographical growth in the 18th and 19th centuries. According to Luquet (*1926*), Saulzet-le-Froid and Vernet, before the replanting of trees, were among the region's most deforested villages in the 19th century.

The end of the 19th and the 20th centuries are marked by the appearance of *Picea* [E-h]. Tree replanting began in the second half of the 19th century under the impetus of the Count of Montlosier (Michelin *1995*). A modern phase of agricultural decline is in great part explained by massive emigration

The organic matter which was strongly degraded at the top of the sequence is the result of a trial of using the peat marsh. In 1978, a drainage ditch covering all the marshland from the northeast to the southeast, caused a decrease in the water level, partially drying out the peat marsh. The biotope law enacted in 1988 terminated any plans for exploiting the narse.

Conclusions

A multidisciplinary study of the narse d'Espinasse provides information on the socio-economic changes in rural life in this region. Human occupation is seen as early as the Neolithic, at the start of the sedimentary record. The Neolithic-Bronze Age transition coincides with a more intense human influence on the environment, whereas the La Tène-Gallo-Roman transition period was the first major turning point in human impact. This is shown first by the near extinction of beech and fir and secondly by the first signs of mixed agro-pastoral activity. Later, in the 11th – 13th century period, came the second turning point, with a noticeable difference at Espinasse. In Aubrac (Beaulieu et al. *1985*; Galop, in press) or in the Cézallier (Guenet *1986*), the intense agro-pastoral activity characteristic of this period was particularly marked by an intensification of deforestation linked to the establishment of religious communities. At Espinasse, this is related to the consolidation of lands that were already considerably improved by voluntary landowners policies. Finally, modern rural desertification and the recent planting of trees are the last changes of any significance.

The two isolated observations of *Fagopyrum* are the oldest finds of this taxon in the entire Massif Central. Buckwheat is observed in relation to various sites in France in the Neolithic—however, it is primarily recorded in relation to Gohaud in Saint-Michel-Chef-Chef on the Atlantic coast (Visset *1979*; Visset et al. *in press*)—as well as from the middle Bronze Age at the Sciotat on the English Channel (Clet-Pellerin *1985*) and even from the Iron Age (Marguerie *1992*). Nevertheless, it is still not possible to be certain of Neolithic buckwheat culture in the Espinasse area since the indications from the French Massif Central are, until today, scarce and isolated.

The present pollen analysis provides significant methodological considerations. It particularly underlines, in terms of the study of anthropization dynamics, the benefits of pollen analysis of a dilated sedimentary record. Also, it again poses the problem of the local vegetation belt (Cyperaceae, *Equisetum*), which can render the pollen record spurious. Excluding these taxa from the calculation sum does not always represent a solution to alleviate this filtering and destructive effect. It is more important that so many anthropogenic pollen indicators are greatly under-represented, cereals being the prime example.

The aim of this multidisciplinary study, here taking advantage of previous archaeological and historical work, was to be directly placed at the interface of human and natural sciences. It was motivated by the interest which today requires the historian and the ecologist, as G. Bertrand had wished almost thirty years ago, to study *these concrete situations of balance and unbalance between the peasant communities and their rural surroundings* (Bertrand *1975*).

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References

Beaulieu, J.L. de, Goeury, C. (1987). Zonation automatique appliquée à l'analyse pollinique: exemple de la narse d'Ampoix (Puy de Dôme). Bulletin de l'Association Française pour l'Etude du Quaternaire, 49–61

Beaulieu, J.L. de, Pons, A., Reille, M. (1985). Recherches pollenanalytiques sur l'histoire tardiglaciaire et holocène de la végétation des monts d'Aubrac (Massif central, France). Review of Palaeobotany and Palynology, 44, 37–80

Beaulieu, J.L. de, Pons, A., Reille, M. (1988). Histoire de la flore et de la végétation du Massif central (France) depuis la fin de la dernière glaciation. Cahiers de Micropaléontologie, 3, 5–36

Behre, K.E. (1992). The history of rye cultivation in Europe. Vegetation History and Archaeobotany, 1, 141–156

Bertrand, G. (1975). Pour une histoire écologique de la France rurale. In: Histoire de la France Rurale (Duby, G., et Wallon, A., dir.), Editions du Seuil, 1

Beug, H.J. (1975). Man as factor in the vegetational history of the Balkan Peninsula. In: Problems of Balkans flora and vegetation. Proceedings of the First International Symposium on Balkan Flora and Vegetation , Varna Sofia, 72–77

Bourdon, S., Laggoun-Defarge, F., Maman, O., Disnar, J.R., Guillet, B., Derenne, S., Largeau, C. (2000). Organic matter sources and early diagenetic degradation in a tropical peaty marsh (Tritrivakely, Madagascar). Implications for environmental reconstruction during the Subatlantic. Organic Geochemistry, 31, 421–438

Brunhes, J., Coquillard, P., Gueugnot, J. (1990). Une tourbière basique d'altitude. Comptes Rendus des Ve Rencontres Interannuelles du Groupe d'Etude des Tourbières, Haute-Loire

Camus, G. (1975). La Chaîne des Puys (Massif central, France). Etude structurale et volcanologique. Thesis, Clermont-Ferrand. Annales des Sciences de l'Université de Clermont, 56

Chapeau, A., Claval, J.C. (1985). Prospections et fouilles au Puy de Montenart, Campagne 1984, Revue du CERAA, 5, 33–50

Charbonnier, P. (1968). Les villages disparus dans la région des Dômes. Bulletin philologique et historique, 357–376

Charbonnier, P. (1984). L'élevage de montagne dans les Monts Dore du XIVe au XVIIIe siècles. Extrait des Actes du Colloque International Elevage et vie pastorale, Clermont, Juin 1982, Institut d'Etudes du Massif central, Clermont-Ferrand, 227–247

Clet-Pellerin, M. (1985). Synthèse palynologique de quelques sites archéologiques de Normandie depuis le Néolithique. Actes des Journées du 25–26–27 janvier 1984, 425–442

Daget, P. (1979). Etudes sur la végétation du Massif central. III. Place du Pin sylvestre dans le climax du Hêtre en Margeride. Bulletin d'Ecologie, 10, 315–325

Dubois, G., Dubois, C., Firtion, F. (1945). La narse d'Espinasse ou tourbière du Puy de l
Enfer. Bulletin de la Sontpellier, 20–26 août 1998.

Fournier, G., Fournier, P.F. (1983). La vie pastorale dans les montagnes du centre de la France. Recherches historiques et archéologiques. Bulletin Historique des Sciences d'Auvergne, 91, 199–290

Gaillard, M.J., Birks, H.J.B., Emanuelsson, U., Karlsson, S., Lagerås, P., Olausson, D. (1994). Application of modern pollen/land-use relationships to the interpretation of pollen diagrams – reconstructions of land-use history in south Sweden, 3000–0 BP. Review of Palaeobotany and Palynology, 82, 47–73

Galop, D. (1998). La forêt, l'homme et le troupeau. Six millénaires d'anthropisation du massif pyrénéen de la Garonne à la Méditerranée. Contribution palynologique à l'histoire de l'environnement et du paysage pyrénéens. Thèse de Géographie, Toulouse, Université de Toulouse-le Mirail

Galop, D. (in press) Activités agro-pastorales et dynamiques paysagères sur le plateau de l'Aubrac au cours des deux derniers millénaires à partir des données polliniques. Documents d'Archéologie Française—Aubrac

Guenet, P. (1986). Analyse pollinique de la tourbière de Chambedaze et recherches pollenanalytiques dans les monts Dore et le Cézallier, Massif central, France. Thèse, Université d'Aix-Marseille III, Paléoécologie

Hjelle, K.L. (1999). Modern pollen assemblages from mown and grazed vegetation types in western Norway. Review of Palaeobotany and Palynology, 107, 55–81

Jouannet, M., Provost, C. (1990). Carte archéologique de la Gaule. Le Puy de Montenart, 2, 313–315

Juvigné, E., Lousberg, N., Gewelt, M. (1988). Evolution morpho-sédimentaire de la narse d'Espinasse (Massif central, France). Revue des Sciences naturelles d Auvergne, 53, 7–14

Laggoun-Défarge, F., Beaulieu, J.L. de, Guillet, B., Miras, Y., Reille, M. (1998). Origin and depositional conditions of organic matters accumulated during the Sub-boreal / Subatlantic in Espinasse ‘narse’ (Massif central). Paleo-environmental reconstruction. Actes du congrès mondial de Science du sol sur CDRom, Montpellier, 20–26 août 1998

Lemée, G. (1942). Recherches sur l’histoire forestière postglaciaire en Auvergne. III. Modifications forestières et climatiques dans les Monts Dore d’après l’analyse pollinique. Revue des Sciences Naturelles d’Auvergne, 8, 83–125

Lhéritier Dr (1911). Notes sur l’archéologie gallo-romaine des environs de Saint-Amand-Tallende. Revue d’Auvergne, 187–207

Luquet, A. (1926). Essai sur la géographie botanique de l’Auvergne. Les associations végétales du massif des Monts Dore. Polycopie de thèse, Faculté des Sciences de Paris, Saint Dizier

Marguerie, D. (1992). Evolution de la végétation sous l’impact humain en Armorique du Néolithique aux périodes historiques. Travaux du Laboratoire d’Anthropologie de Rennes, 40

Meyers, P.A., Lallier-Vergès, E. (1999). Lacustrine sedimentary organic matter records of Late Quaternary Paleoclimates. Paleolimnology, 22, 345–372

Michelin, Y. (1995). Les jardins de Vulcain. Editions de la Maison des Sciences de l’homme, Paris

Michelin, Y., Vergne, V., Denèfle, M. (2001). Variations des teneurs en éléments minéraux dans un bas-marais holocène: la Vézolle (Chaîne des Puys), premières recherches des manifestations anthropiques. Quaternaire, 12, 31–41

Miras, Y., Vergne, V., Guenet, P., Surmely, F. (in press). Le Massif central: premières traces d’anthropisation révélées par l’analyse pollinique des zones humides corrélées aux données archéologiques. Annales Littéraires de Franche-Comté

Reille, M., Pons, A., Beaulieu, J.L. de (1992). Late and postglacial vegetation, climate and human action in the French Massif Central. Cahiers de Micropaléontologie, 7, 1–2, 93–106

Stuiver, M., Reimer, P.J. (1993). Extended 14C database and revised CALIB radiocarbon calibration program. Radiocarbon, 35, 215–230

Visset, L. (1979). Recherches palynologiques sur la végétation Pléistocène et Holocène de quelques sites du district phytogéographique de Basse Loire. Bulletin de la Société naturelle de l’Ouest France, suppl. hors sér.

Visset, L., Cyprien, A.L., Ougerram A., Barbier, D., Bernard, J. (in press) Les indices polliniques d’anthropisation précoce dans l’ouest de la France. Les cas de *Cerealia*, *Fagopyrum* et *Juglans*. Annales Littéraires de Franche-Comté.