

Anne-Laure Cyprien · Lionel Visset ·  
Nathalie Carcaud

## Evolution of vegetation landscapes during the Holocene in the central and downstream Loire basin (Western France)

Received: 27 May 2003 / Accepted: 2 June 2004 / Published online: 20 July 2004  
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**Abstract** Nine sites along the downstream and middle section of the Loire river at Cordemais (Loire Atlantique, France) situated in the estuary to Saint-Nicolas-de-Bourgueil (Indre et Loire, France) were investigated. Interdisciplinary studies combined palynology, geography, archaeology, sedimentology and history, thus enabling us to reconstruct the evolution and the long-term response of the Loire valley ecosystem to natural variations and anthropogenic pressure from the Preboreal to the present in an integrated manner. The Atlantic marine transgression (between 7000 and 5000 B.P.) caused the level of brackish water to increase at Oudon between 6740<sup>+205</sup>/<sub>-200</sub> and 5010<sup>+115</sup>/<sub>-100</sub> B.P. This phenomenon, which was the first of its kind to be detected near the central Loire region (approximately 80 km from the current mouth of the Loire river), was accompanied by the development of subhalophile vegetation (Chenopodiaceae) and the appearance of dinoflagellate cysts. A regressive phase occurred during the Subboreal, about 4500 B.P., and led to the erosion of most of the estuarine sediments and to the disappearance of plant species linked to salinity at Oudon: peat deposits built up at most other sites. Human activities had an early effect; moderate deforestation took place at Champtocé about 6600 B.P. as farming was already orientated towards rearing animals. However, possibly cultivated plants were present towards the middle and the end of the Neolithic period (wheat, rye, buckwheat, flax) at about 5600 B.P. and chestnut and walnut were probably exploited in the Loire valley region at about 4600 B.P. The Bronze Age seemed to mark a phase when societies settled down (planting of vineyards) and deforestation peaked

from the Gallo-Roman period onwards. The textile industry (flax, hemp), in the context of crop rotation set up during the Iron Age, developed rapidly during the Middle Ages, whereas nowadays the rearing of animals is the dominant activity in the Loire Valley, following the introduction of maize into the region in 1950.

**Keyword** Palynology · Palaeoenvironment · Loire Valley · Holocene · Marine transgression · Human impact

### Introduction

As a major route for exchange and communications, the Loire River has attracted human populations for millennia. This is attested to by the numerous archaeological remains found in the Loire valley (dugout canoes, evidence of harbours, standing stones, dolmens, etc.). The oldest of these show signs of human presence during the Weichselian period, such as the Roc-en-Pail rock shelter at Chalonnes-sur-Loire (Visset 1980) or the Pierre Meslière site (Ancenis/Saint-Géréon), which has been dated to Palaeolithic times. The two main streams of neolithisation in Western Europe (Danubian and Cardial) appear to have met at a later stage along the banks of the Loire (Visset et al. 2002).

Human communities have succeeded each other for millennia along the Loire Valley. At first nomadic, over time they settled, thus gradually helping to shape the landscape as they cleared forests and planted crops.

This paper describes how the regional vegetation evolved at nine sites (thirteen surveys) in the central and downstream areas of the River Loire, and provides a chronology of interaction between human populations and their environment along the river valley (Fig. 1).

Investigations conducted during the last few years in various regions (Marambat 1995; Leroyer 1997; Puertas 1997; Galop 1998; Trément 1999; Barbier 1999; Ouguerram 2002; Cyprien 2002) have demonstrated the importance and fruitfulness of an interdisciplinary approach that promotes an overall understanding of the way

A.-L. Cyprien (✉) · L. Visset  
Laboratoire d'Ecologie et des Paléoenvironnements Atlantiques,  
UMR 6566- CNRS, Faculté des Sciences et des Techniques,  
2 rue de la Houssinière, BP 92208, 44322 Nantes Cedex 03, France  
e-mail: geminaecol@svt.univ-nantes.fr

N. Carcaud  
Laboratoire des Sciences de l'Environnement et de  
l'Aménagement,  
UFR Sciences, Université d'Angers,  
35 rue de la Barre, site Montesquieu, 49000 Angers, France

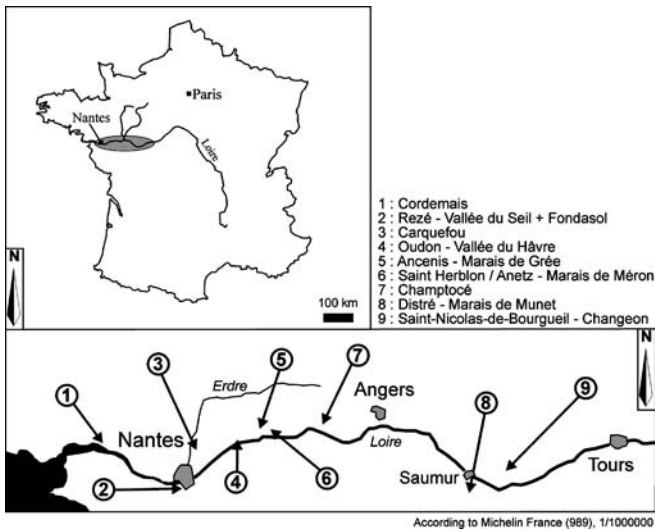


Fig. 1 Location of the study area

environments function. By combining palynology, sedimentology, geography and archaeology in our research, we have gained an overall view of the impact of human societies on the environment (cultivation, deforestation, habitats, herding, ponds, mills, etc.) from the preboreal period to the present.

Other reference studies have been carried out in the wider region of Western France, along the Armorican coast (Morzadec-Kerfourn 1974), the lower Loire (Visset 1979), in the Loire estuary (Voeltzel 1987), the Breton-Vendée marshes (Bernard 1996), the Paris Basin (Leroyer 1997), the northern Mayenne area in Normandy (Barbier 1999) and, recently, in the Erdre river valley (Ouguerram 2002).

Our relatively large study area (about 180 km in length) has proved to be highly varied, since it covers the Loire estuary (at Cordemais), a palaeo-channel (at Rezé), the marshlands adjacent to the Loire (Oudon, Ancenis, Méron, Champocé) and the wetlands of Carquefou, Changeon and Distré, these latter being more distant from the river's influence (Fig. 1).

## Materials and methods

Sediment samples were collected by using a motor-driven GIK drill (10 cm diameter) (Visset and Hauray 1980, 1988) or a percussion drill. The majority of sediments were mud. Sampling for pollen analysis was performed every 5 cm (sometimes at an interval of 4 or 3 cm). For pollen extraction mud samples were treated with Thoulet's solution and bog sediments by the classic method for peat. Pollen diagrams were constructed using G3PAL software. For each sample, about 300 to 400 pollen grains were counted. *Alnus* (local vegetation) and *Pinus* were excluded from calculation for general pollen diagrams to avoid masking the pollen representation of other species (the calculation sum is also about 300 grains). Portions of the most representative diagrams are selected for each period. In these diagrams pollen groups are formed as follows according to their ecological, biological or anthropic characteristics (Behre 1981):

*Cropland plants:*

*Apophytes:*

*Ruderals:*

*Centaurea cyanus, Papaver*

*Rumex, Mercurialis annua*

*Plantago, Convolvulus arvensis, Polygonum aviculare, Cuscuta, Brassicaceae, Chenopodiaceae, Caryophyllaceae, Artemisia, Ranunculaceae, Potentilla, Trifolium, Solanaceae, Urticaceae, Lamiaceae, Alchemilla, Valerianella, Fabaceae, Compositae (Asteraceae, Cichorioideae)*

*Heathlands:*

*Ulex, Calluna (Erica), Campanulaceae, Asphodelus, Polygala, Gentiana pneumonanthe, Helianthemum*

*Aquatic plants:*

*Myriophyllum, Nymphaea, Nuphar, Potamogeton, Lemna, Nymphoides, Utricularia, Sagittaria, Hydrocharis, Ranunculus aquatilis, Menyanthes, Callitriche, Hotttonia*

*Paludal plants:*

*Typha, Sparganium, Iris, Ludwigia, Alismataceae, Menyanthes, Anagallis, Lysimachia, Lythrum, Filipendula, Valeriana, Polygonum persicaria, Rumex hydrolapathum, Hydrocotyle, Equisetum, Apiaceae (Apium), Rubiaceae, Scrophularia aquatica, Sanguisorba minor, Thalictrum, Oenotheraceae (Epilobium)*

*Bushes:*

*Hedera, Lonicera, Cornus, Evonymus, Viburnum, Sambucus, Ligustrum, Prunus, Viscum, Rubus, Ilex*

*Shrubs of humid zones: Salix, Populus, Rhamnus, Myrica*

Only the most significant pollen curves are shown.

Radiocarbon dating was performed at the Laboratory of Isotope Geochemistry in Tucson, Arizona. The results are summarised in Table 1.

## Results and discussion

### Dynamics of post-glacial vegetation

#### *The preboreal period (10000–8900 B.P.)*

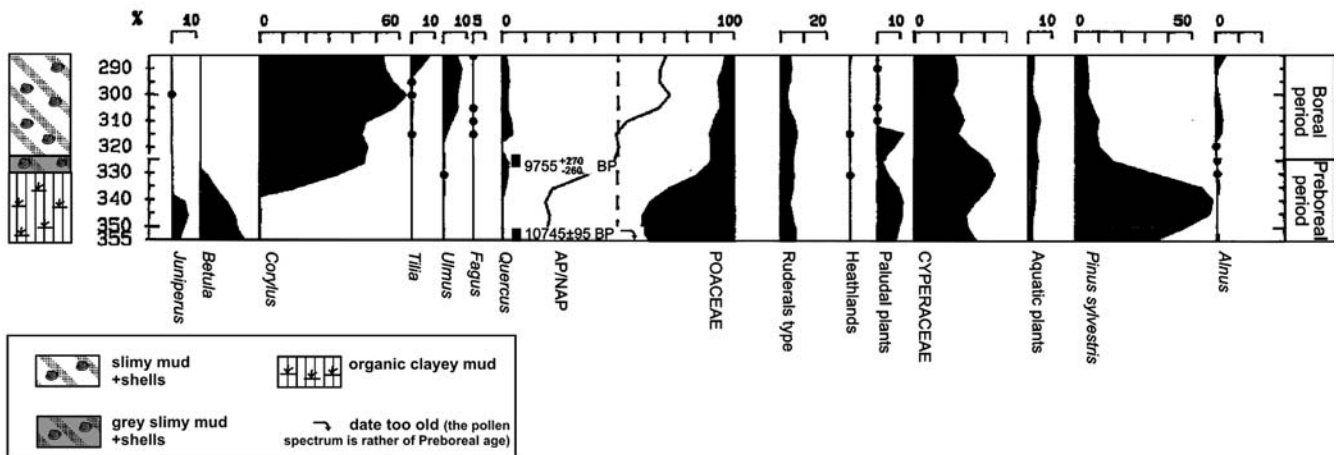
The preboreal period is represented only at the Munet site (Fig. 1, site 8). The valley began to fill in during the early Holocene period, a process characterised by the deposition of loamy sediment as far as the Atlantic coast. During the preboreal period alluvial sedimentation of the flood loam type occurred in calm waters. The hillsides were initially covered with *Pinus* (pine) (Fig. 2) with some *Betula* (birch) and *Juniperus* (juniper) that subsequently gave way to *Corylus* (hazel) (9755 B.P.). Mesothermophilous species such as *Ulmus* (elm) and *Quercus* (oak) heralded an improvement in climatic conditions (rise of temperatures). Locally temporarily flooded mud flats were covered with Cyperaceae, as evidenced by a small number of aquatic and marshland species.

#### *The Boreal period (8900–7800 B.P.)*

Forests with *Corylus*, *Quercus*, *Ulmus* and *Tilia* (lime) became established, effectively protecting hill slopes, thus probably accounting for the low rate of sedimentation and the fine grain of the minerals washed down to the marshes

**Table 1** Radiocarbon dates, calibration after Stuiver and Reimer (1998)

Site	Lab. No	Depth (cm)	Material dated	Age (B.P.)	Age (calibrated, 2σ range)
Ancenis	A-11316	560–563	Grey mud	5680±180	4937 (4498) 4052 B.C.
Ancenis	A-10106	470–475	Peaty mud	4690±80	3644 (3503, 3428, 3381) 3140 B.C.
Ancenis	A-11315	380–385	Peat	4020±60	2856 (2564, 2522, 2497) 2352 B.C.
Ancenis	A-11314	240–244	Peat	2645±55	902 (805) 764 B.C.
Ancenis	A-10105	109–114	Peat	1050±50	A.D. 891 (997) 1149
Ancenis	A-11312	70–75	Peat	975±50	A.D. 982 (1026) 1188
Carquefou fossé	A-10042	109–114	Black peat	2295±60	478 (388) 201 B.C.
Carquefou fossé	A-10330	62–67	Ligneous peat	2175±85	399 (201 B.C.) A.D. 2
Carquefou tranchée	A-10318	45–50	Peat	515±55	A.D. 1304 (1418) 1466
Champtocé	Beta-138642	640–645	Grey mud	6630±40	5632 (5609, 5589, 5558) 5481 B.C.
Champtocé	A-11308	550–555	Grey mud	5375±175	4547 (4242) 3795 B.C.
Champtocé	A-10197	445–450	Peat	4195±85	2923 (2875, 2796, 2792) 2498 B.C.
Cordemais	A-9879	675–680	Black mud	5615 <sup>+165</sup> / <sub>-170</sub>	4834 (4456) 4044 B.C.
Méron	A-10770	414–418	Peaty mud	4685±110	3662 (3502, 3430, 3380) 3098 B.C.
Méron	A-11465	345–350	Peat	4020±50	2835 (2564, 2522, 2497) 2459 B.C.
Méron	A-11464	275–280	Muddy peat	3355±70	1745 (1680, 1670, 1658, 1651, 1637) 1519 B.C.
Méron	A-10769	232–237	Muddy peat	3120±70	1521 (1407) 1134 B.C.
Méron	A-10768	163–168	Muddy peat	2075 <sup>+95</sup> / <sub>-90</sub>	376 (89, 78, 57 B.C.) A.D. 125
Méron	A-11463	120–125	Organic mud	1420±70	A.D. 473 (643) 765
Munet	A-9842	350–355	Organic clayey mud	10745±95	11049 (10922) 10464 B.C.
Munet	A-9841	325–330	Grey slimy mud	9755 <sup>+270</sup> / <sub>-260</sub>	10339 (9229) 8340 B.C.
Munet	A-9840	265–270	Peat	4495±55	3365 (3326, 3320, 3314, 3229, 3172, 3160, 3117, 3110, 3104) 2927 B.C.
Munet	A-9839	250–255	Slimy organic mud	4255±65	3016 (2884) 2636 B.C.
Munet	A-9838	225–230	Slimy organic mud	4050±60	2863 (2575, 2508, 2504) 2461 B.C.
Oudon	A-11311	1105–1110	Peaty mud	6740 <sup>+205</sup> / <sub>-200</sub>	6012 (5657, 5653, 5638) 5304 B.C.
Oudon	A-10100	979–984	Peaty mud	6650 <sup>+100</sup> / <sub>-95</sub>	5728 (5615, 5585, 5561) 5386 B.C.
Oudon	A-10099	885–890	Muddy peat	5010 <sup>+115</sup> / <sub>-100</sub>	4039 (3786) 3539 B.C.
Oudon	A-11152	680–685	Muddy peat	4410±60	3341 (3078, 3071, 3025) 2897 B.C.
Oudon	A-11151	580–585	Muddy peat	4050 <sup>+135</sup> / <sub>-130</sub>	2912 (2575, 2508, 2504) 2200 B.C.
Oudon	A-11310	525–530	Muddy peat	3530±55	2025 (1880, 1837, 1831) 1692 B.C.
Oudon	A-11150	450–454	Muddy peat	2615±75	904 (800) 524 B.C.
Oudon	A-10098	320–325	Muddy peat	2350±80	762 (400) 204 B.C.
Oudon	A-11149	200–205	Organic mud	2070±105	385 (87, 81, 54 B.C.) A.D. 131
Oudon	A-11309	90–95	Organic mud	595±65	A.D. 1282 (1328, 1345, 1394) 1438
Vallée du Seil	Beta-135361	235–240	Clayey sand	1730±40	A.D. 224 (261, 278, 324, 331, 335) 416

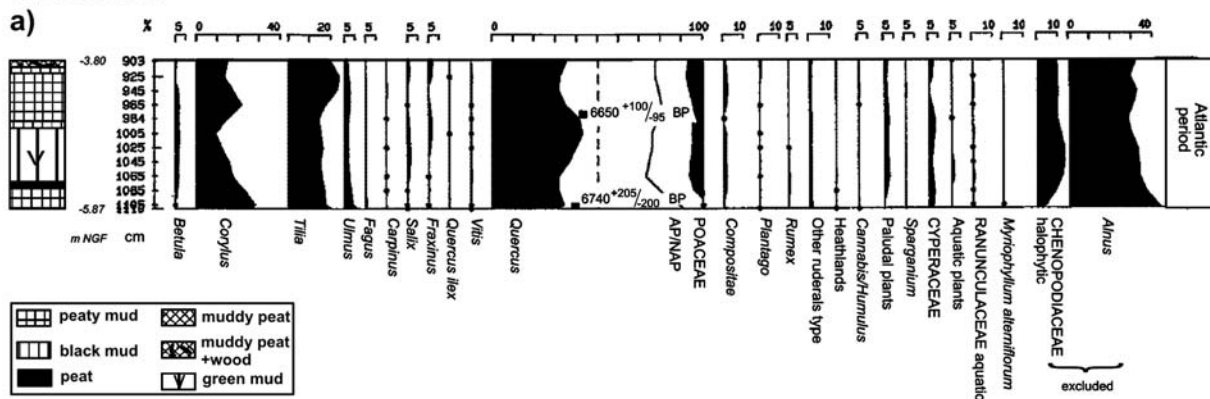
**Fig. 2** The Preboreal and Boreal period, Munet site

as far as the Atlantic ocean. These marshes, which were flooded in the early boreal period (presence of aquatic and marsh species such as *Typha* and *Sparganium*), subsequently began to dry out (Fig. 2).

#### *The Atlantic period (7800–5700 B.P.)*

The hillsides were densely wooded until the end of the Atlantic period, with a mixture of *Quercus* and *Tilia* taking over more strongly from *Corylus* towards the end

## Oudon site



## Cordemais site

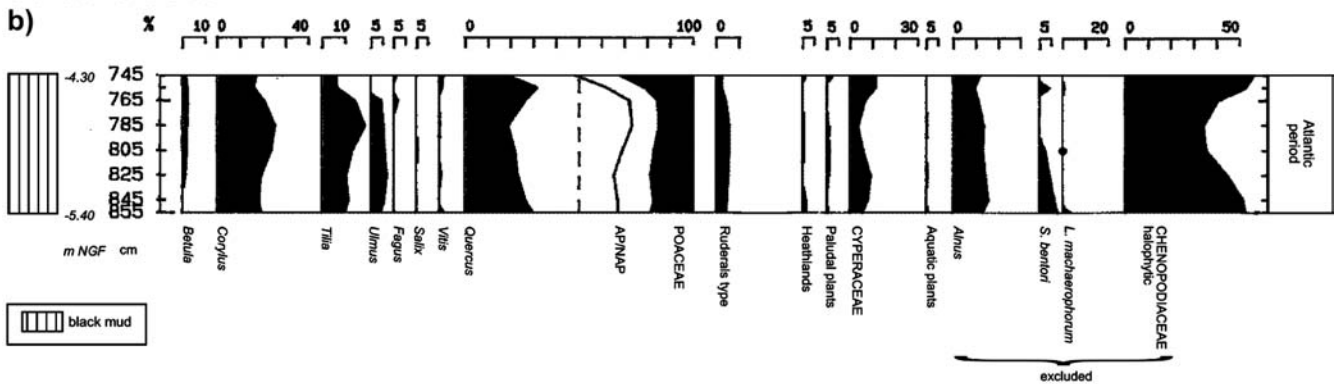


Fig. 3 The Atlantic period. Oudon site (a), Cordemais site (b)

of the period. *Fagus* (beech) is in evidence at Oudon (Fig. 1, site 4; Fig. 3a) and at Cordemais (Fig. 1, site 1; Fig. 3b) in the Loire estuary. *Quercus ilex* (holm oak) appears only at Oudon towards 6650 B.P. (Fig. 3a); the Hâvre valley seems to have offered the right ecological conditions for its establishment, although the species remained infrequent until the early subatlantic period. In the valley of the Erdre, a tributary of the Loire, Ouguerram (2002) points out the station-dependent character of *Quercus ilex* during the Atlantic period. Planchais (1967) had already referred to evidence of its occurrence during the earlier boreal period. Today, according to many authors, this thermophilous species frequently occurs spontaneously along the Atlantic coast. According to Dupont (2001), its northern limit of spontaneous growth is on the island of Noirmoutier (Vendée, France), and it has almost certainly been introduced further north. The data collected in the Erdre and Loire valleys provide further confirmation that the northern limit of spontaneous growth of holm oak during the Atlantic period reached at least as far as the Erdre valley. Only the marshy areas around Oudon (Fig. 3a) were covered by *Alnus* (alder), with *Vitis* (wild vines). The valley bottom was filled by mainly loamy deposits in the Munet marsh and at Oudon, where sedimentation occurred in stagnant waters.

#### Two exceptions: Cordemais and Oudon

At Cordemais, not far from the freshwater marshes, a form of herbaceous vegetation (chenopodiaceae and Poaceae) was found which is typical of halophytic environments (Fig. 3b) and bears witness to the formation of a salt marsh where dinoflagellate cysts (such as *Spiniferites bentori* or *Lingulodinium machaerophorum*) were discovered. These cysts are good markers of salinity, Mozadec-Kerfourn (1976, 1992) noting that *Spiniferites bentori* is found in abundance in the maritime domain while *Lingulodinium machaerophorum* is associated with brackish environments.

At Oudon, about 80 km from the present-day mouth of the Loire, this phenomenon is less evident and more limited in time, with green silt deposited in calm, slow-moving waters. The presence of sub-halophytic vegetation made up of chenopodiaceae, also associated with dinoflagellate cysts (though less numerous than at Cordemais), suggests that a mixture of brackish waters may have penetrated the Hâvre valley from (at least) 6740 B.P. to 5000 B.P. (Fig. 3a). This phenomenon appears to have occurred at the same time as the marine transgression which is known to have taken place from 7000 to 5000 B.P. (Mozadec-Kerfourn 1974; Visset 1979; Bernard 1996).

### *The Subboreal period (5700–3600 B.P.)*

The landscape began to change radically during the Subboreal period. Variations in sea level, transgressive around 5700 B.P., regressive around 4500 B.P. (Visset et al. 1994, 1995, 1996), had repercussions in the Loire valley where the river appears to have been indirectly affected by these oscillations, with evidence of changes in its hydrological regime.

Morzadec-Kerfourn (1974) considers that the Subboreal period along the Armorican coastline was a relatively humid time during which the marshes became established. This was the case in numerous marshlands where the heightening of the water regime is reflected in a clear increase in paludal taxa (*Lysimachia*, *Sparganium*, *Typha*, etc.), magnocaricacae and alders (except when the water level was too high). These observations appear to be contemporary with the rise in sea level known to have occurred at about 5000 B.P.

From the beginning of the regressive phase, around 4500 B.P., peat deposits appeared at most sites, despite the observed increase in waterway flow, reflected in the sedimentology by an increase in fine and coarse-grained sand, both in the Douet river (munet marsh) and the Hâvre (at Oudon).

In the sites near the estuary (Cordemais), marine regression caused partial erosion of sediments and, further upstream (at Oudon), a complete withdrawal of brackish waters (disappearance of *Chenopodiaceae*) (Fig. 4a).

In the Munet marsh, a hiatus in sedimentation is apparent before 4500 B.P. This seems to have occurred at the same time as the marine regression phase, whose impact, according to some authors (Gruet 1978; Cassen et al. 1999), is still visible today about 150 km away from the coast, especially in the rate of burial of standing stones and dolmens (e.g. at Champtocé or Ancenis) (Ménanteau 1973). However, is it really likely that the withdrawal of the sea could have had an impact on a place some 180 km away from the present-day shoreline, while peat deposits were building up in other sites further downstream? Could this not rather be explained by local phenomena occurring upstream? At present few examples have been found in the region, although there is evidence in some places along the Loire and Authion valleys (not far from the Munet marshes) of highly contrasting hydrodynamics during the Atlantic and Subboreal periods (Visset et al. 1999). It was also between 4700 and 4300 B.P. that silty coastal ridges began to form near river mouths, permanently halting the penetration of seawater (Oudon) and gradually cutting off inland environments from direct marine influences (Cordemais).

The hillsides remained covered with *Quercus* that was gradually replaced by *Corylus* (Fig. 4a) except around Munet (Fig. 4b). *Fagus* also remained, but *Ulmus* and *Tilia* declined throughout the period.

There is evidence of *Buxus* (box wood) around 5600 B.P. in the Loire estuary at Cordemais (Fig. 4c). *Buxus* has already been recorded in the western region by Ouguerram (2002) at around 7350 B.P. (about 6200 cal

B.C.), by Voeltzel (1987) around 6500 B.P. and by Visset (1979) around 5200 B.P., which may indicate the spontaneous presence of this species in a few ecological niches in the region (Bernard 1996), the Cordemais soils and the schist soils around Ancenis (Fig. 1, site 5) appearing to be favourable for its establishment (either very temporary or very localised?).

From the subboreal period onwards, the environment became subject not only to climatic variations but also to the activity of human societies. Some forest clearing, probably associated with the beginnings of livestock farming, (ruderal species and grasses) and cropping (wheat, rye, buckwheat and flax) appeared in the Loire valley.

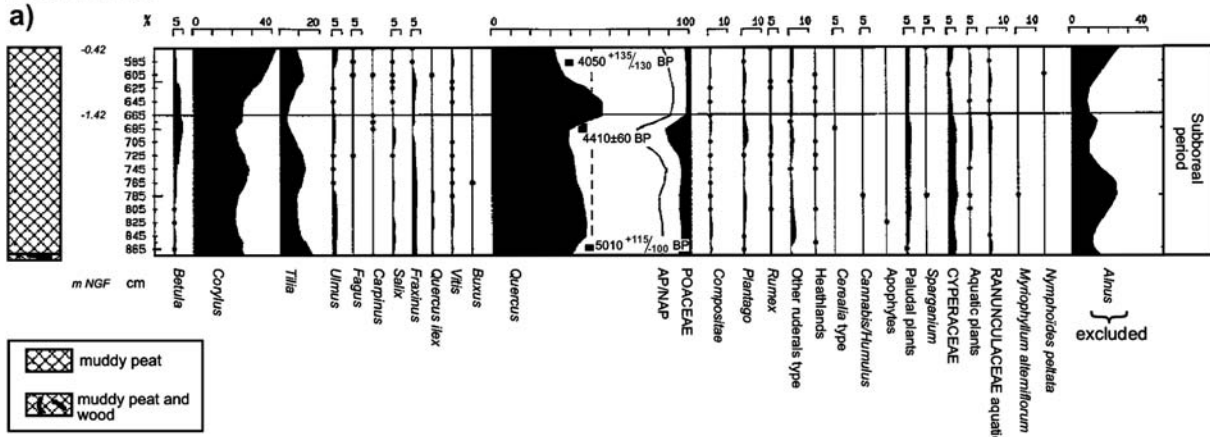
### *The Subatlantic period (3600 B.P. to the present)*

The influence of marine movements during the Subatlantic period (starting in Western France at 3600 B.P., Morzadec-Kerfourn 1974) seems to have been restricted to the estuarine zone, i. e. at Cordemais. Here, where the sediments dating back to the late Subboreal period have been eroded, we also find a hiatus in sedimentation relating to the Bronze and Iron Ages. This could have been the consequence of the succession of regressive movements associated with the lowering of the sea level during the Bronze Age, around 3000 B.P. (Morzadec-Kerfourn 1974; Prigent et al. 1983; Shennan 1986; Pirazzoli 1991; Visset et al. 1994; Marambat 1995; Bernard 1996) and the Iron Age (Prigent et al. 1983). As we saw previously the continental future of the marsh was associated with the establishment of the silty coastal ridges during the second half of the Subboreal period. It should be noted that as a result of these variations, the current level of the sea seems to have been reached at some point between the late Gallo-Roman period and A.D. 1000 (Prigent et al. 1983; Visset 1988).

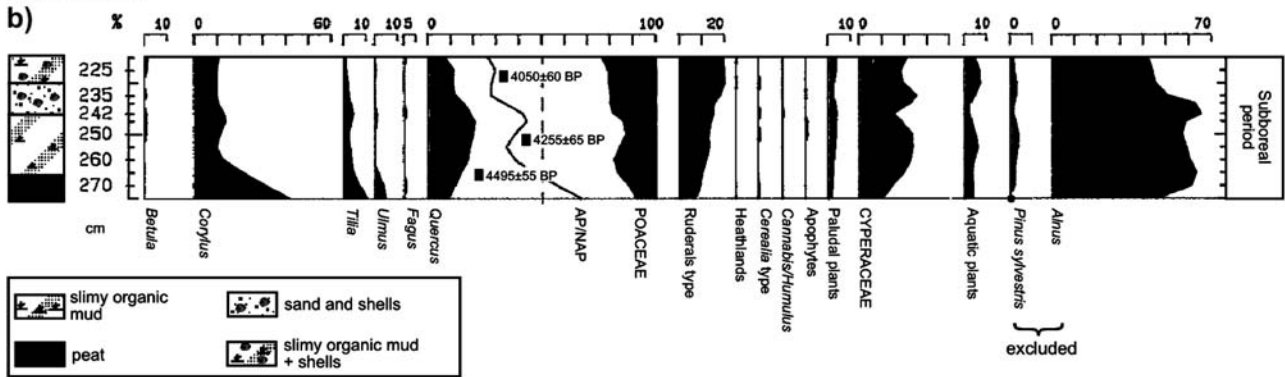
The continuous presence of *Fagus* pollen (Fig. 5) is a characteristic of the Subatlantic period around 3600 B.P. in the Armorican Massif in France, along with the disappearance of *Tilia* (Morzadec-Kerfourn 1974) noted in the Loire valley mainly during the Bronze and Iron Ages around 2350 B.P. at Oudon and 2650 B.P. at Ancenis.

*Quercus ilex* remained (although very infrequent) in the Méron marshes (Fig. 1, site 6) until the Middle Ages, and still exists today at Ancenis, where the schist soils appear to be favourable to its growth. According to Bernard (1996), holm oak could also be encouraged by human activity. The other areas do not seem to have had the right conditions for the establishment of this particular forest species.

Oudon site



Munet site



Cordemais site

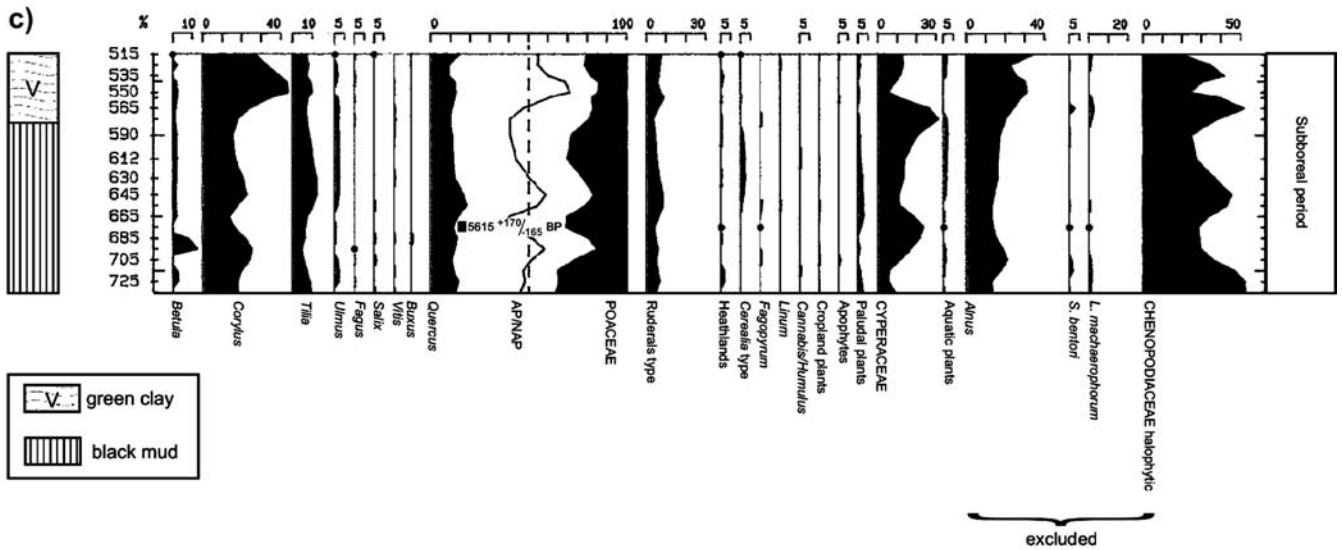


Fig. 4 The Subboreal period. Oudon site (a), Munet site (b), Cordemais site (c)

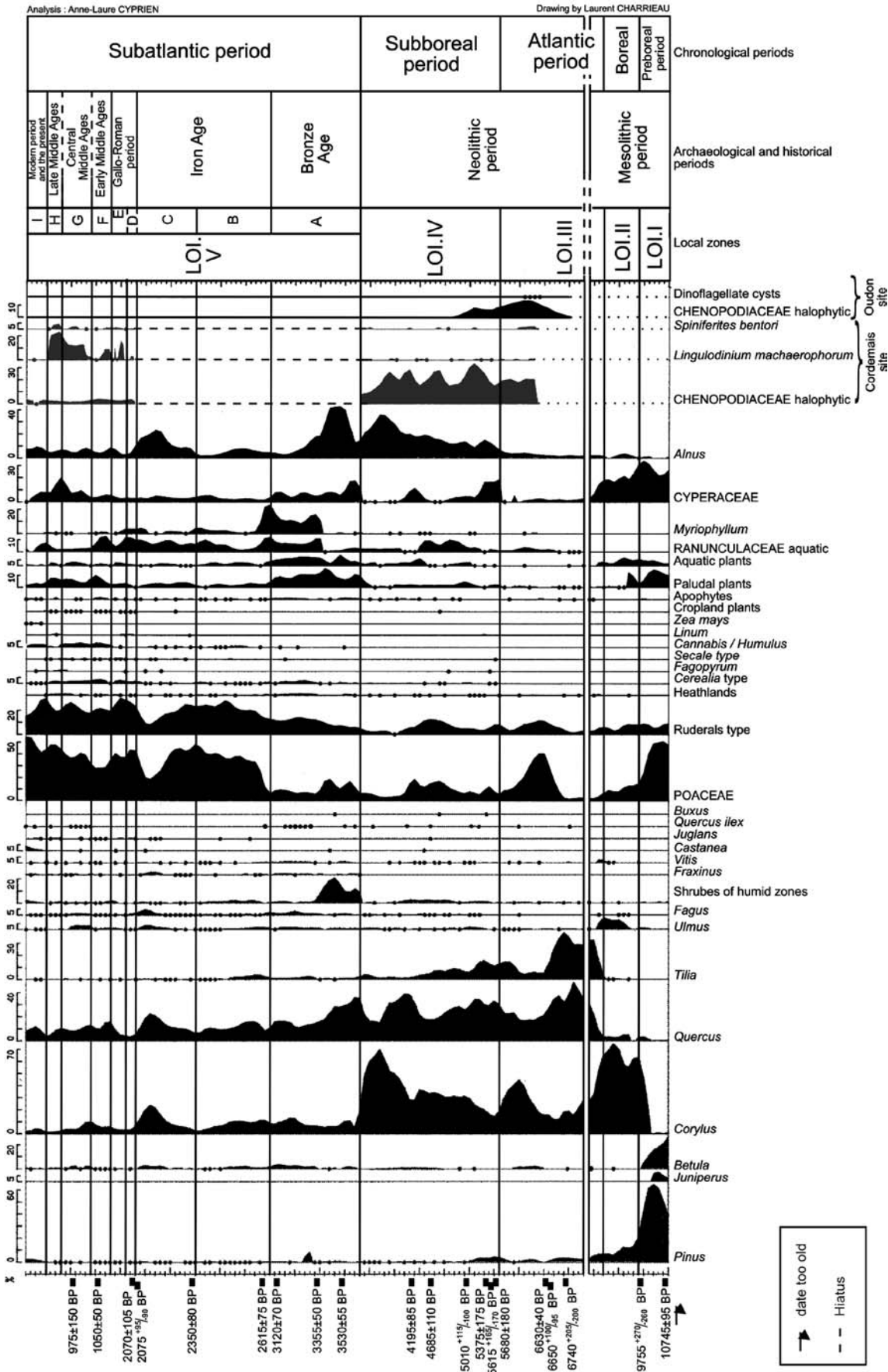


Fig. 5 Composite diagram from the region. Evolution of the plant landscapes from the Preboreal period in the Loire valley

Interactions between human activity and the environment (Fig. 5, LOI.III, IV, V)

### *The Neolithic period 7100–3900 B.P.*

#### *Early Neolithic*

The impacts of human activity probably began at the beginning of the early Neolithic period. Only the site at Champtocé (Fig. 1 site 7; Fig. 6a) reveals early human activity, in the decline of forest cover around 6600 B.P. and in the clear progression of grasses and ruderal species. Livestock farming became established, but it is surprising that there is no evidence of crop farming during this time.

#### *Mid and Late Neolithic*

Forest clearing on a small scale increased in frequency during the mid to late Neolithic period. In addition to livestock farming, which already existed in the early Neolithic period, human societies began to diversify their activities through the adoption of crop farming (Fig. 5).

*Secale* type (rye) (pollen size 70 µm, elongated form) is present from about 5700 B.P. in the Ancenis area (Fig. 6b). Rye is not indigenous in the Loire valley (Fournier 1946). Rye was domesticated and brought to Europe together with other cereals from the Near East, but was not used as a cultivated plant until the Late Iron Age. *Secale* grew in the fields together with cereals as a weed (with a ca. 1000× higher pollen production than other cereals) and was acculturated in Europe much later (unlike *Triticum* and *Hordeum*). Behre (1992) notes that the few pollen grains present indicate a wild variety (already domesticated but not acculturated), with rye cultivation appearing during the Gallo-Roman period in Germany, but only beginning to flourish in the Middle Ages.

Van Zeist (1963) has found *Secale* in West of France during the Subboreal period and Marguerie (1992) notes the presence of this cereal in late Neolithic in a site of Isère.

*Fagopyrum* (buckwheat), *Linum* (flax) and *Cerealia* (cereals) (around 5600 B.P.) are present in the Loire estuary at Cordemais (Fig. 4c). This again supports the findings of various studies that demonstrate the early introduction from the Middle East, especially of *Fagopyrum*, in Western France. Buckwheat occurred sporadically from the late Mesolithic period (Visset et al. 2002) and through the Neolithic and Bronze Ages (Visset 1979), but did not really flourish until the start of the Middle Ages (Voeltzel 1987; Nassiet 1998; Barbier 1999). Some buckwheat pollen was discovered in a neolithic vase from the Somme (Girard 1973). However its cultivation by Mesolithic people is not confirmed as pollen grains are not always good evidence of cultivation and could also have accumulated from the wild.

These plants are found again towards 5400 B.P. at Champtocé (Carcaud et al. 2000) and towards 4600 B.P.

at Ancenis, Oudon and in the Méron marshes. Numerous archaeological remains dating back to the Neolithic period (standing stones and dolmen at Anetz, the Pierre Blanche standing stone at Oudon, la Boire standing stone at Champtocé, etc.) confirm the existence of human populations in the valley. The exception is the Munet marsh where there seems to be no evidence of human occupation (Cyprien et al. 2001a).

*Juglans* and *Castanea* pollen appears at Méron (Fig. 6c) towards 4700 B.P. It should be noted that their introduction had usually been dated to the Gallo-Roman period (Visset 1979). However, walnut has been recorded during the Neolithic period in the Erdre valley (Ouguerram and Visset 2001a), in the Fourneau peat bog in Mayenne (Barbier 1999), in the Morbihan area (Visset et al. 1996), where occurrences are noted at 5425 B.P. (4437–4045 B.C.), then during the early Bronze Age at la Trinité-sur-mer (Visset et al. 1995) in the Nantes region (Barbier and Visset 1997) and finally on the Breton peninsula as from the Iron Age (Marguerie 1992).

Renewed development of hazel and oak woods can be seen towards the end of the Neolithic period (Fig. 6b), associated in some sites with the virtual disappearance of cereals, regression of meadow lands and the establishment of heaths in certain spots.

### *The Bronze Age: 3900–2800 B.P.*

Forest cover on hillsides remained relatively dense although a slow decline began around 3400 B.P. (Fig. 7a), except at the Carquefou (Fig. 1, site 3) and Munet sites. This appears to have encouraged the growth in many areas of *Fagus* and *Corylus*, with the more open environment encouraging hazel pollination (Bégeot 1998).

Pastures and crop fields began to spread. The wild vine pollen occurring in the Atlantic region now forms a continuous curve (in parallel with the presence of cereal and hemp) and may have been cultivated. Ouguerram (2002) notes that *Vitis* could probably be cultivated during the Bronze Age in the Erdre valley. *Cannabis-Humulus* (hemp), which is much in evidence on the Oudon site around 3500 B.P. (Fig. 7b), may also be considered to have been cultivated from about this time as in the Erdre valley (Ouguerram 2002), although the crop did not reach its peak until Mediaeval times.

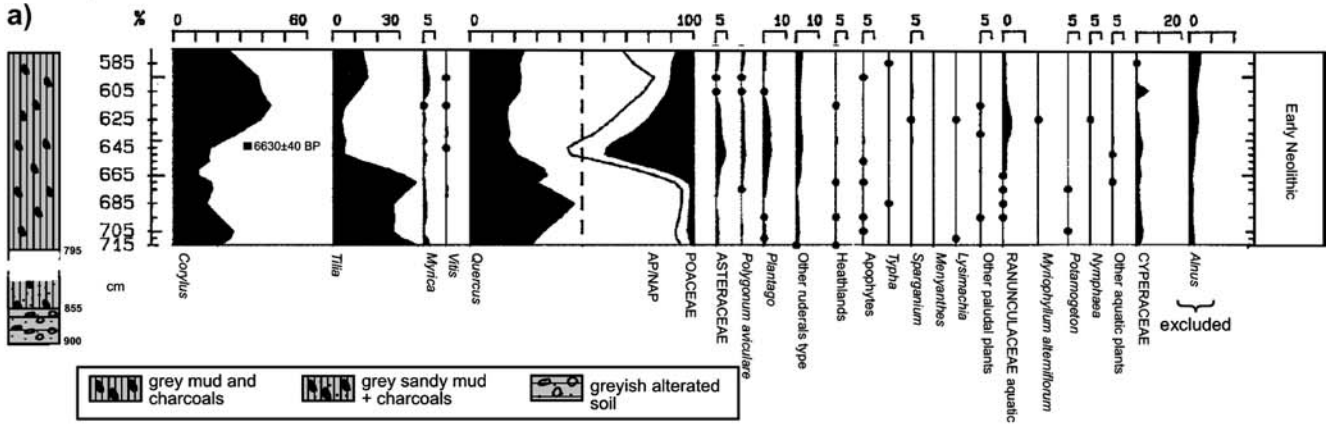
Towards 3100 B.P., forest clearance intensified and the environment gradually opened up.

In many marshlands (Méron, Ancenis, Oudon and Munet), increasing humidity is reflected more or less clearly. Towards 3355 B.P., in the Méron marsh (Fig. 7a), there was considerable development of aquatic plants (such as *Myriophyllum alterniflorum*, aquatic Ranunculaceae, etc.) along with numerous paludal species, attesting to a sea level rise in sinks that gradually asphyxiated the previously extensive alder woods and wetland shrubs.

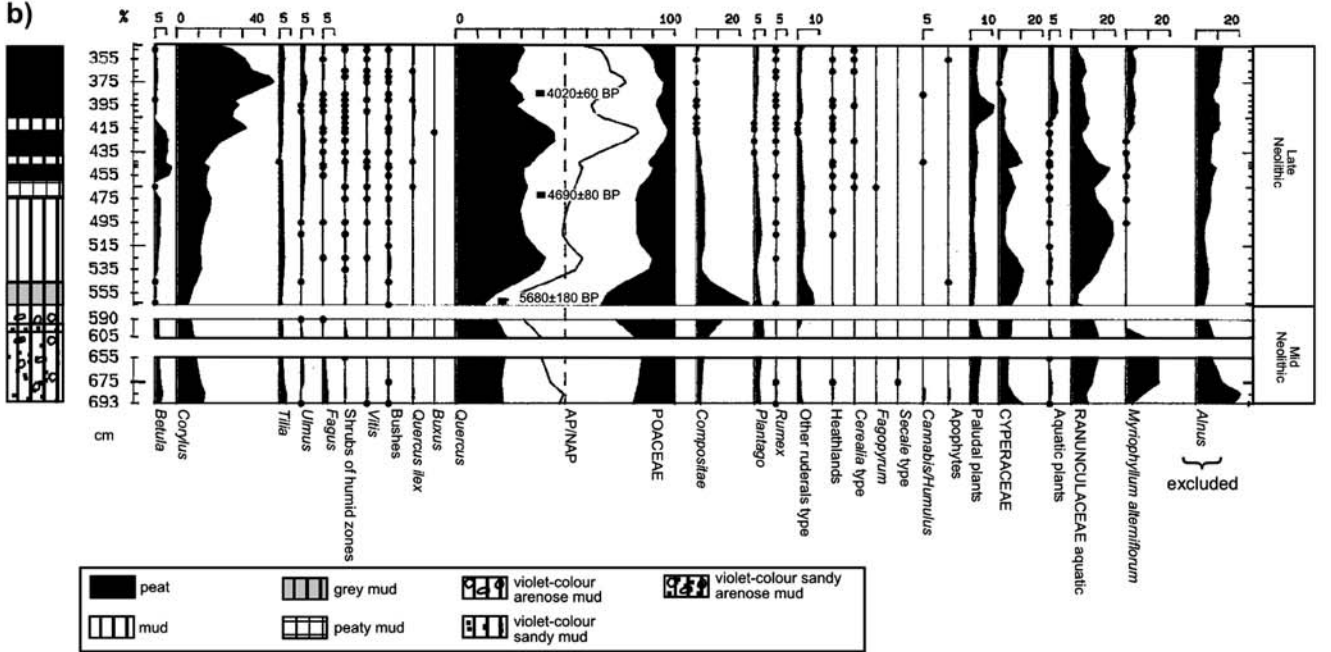
Occurring at the peak of a transgressive episode (Morzadec-Kerfourn 1974; Visset et al. 1995), successive



Champtocé site



Ancenis site



Méron site

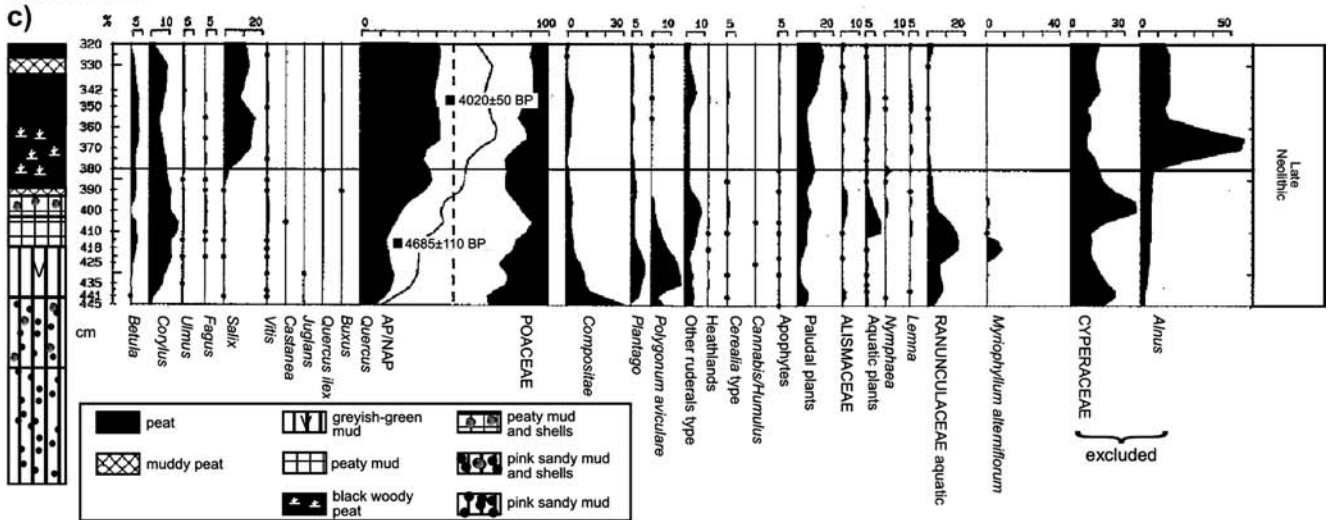
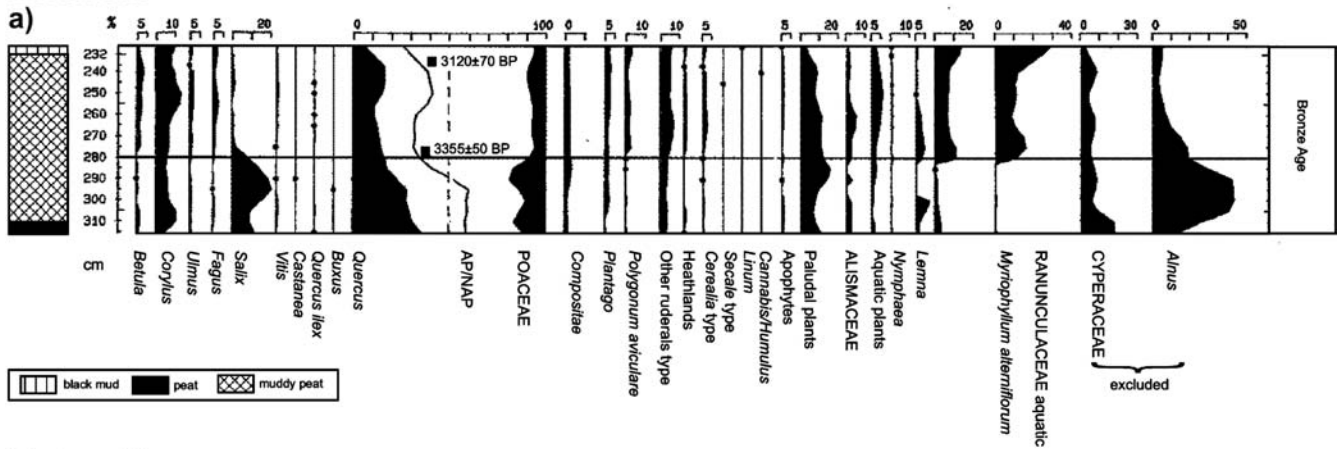


Fig. 6 The Neolithic period. Champtocé site (a), Ancenis site (b), Méron site (c)

## Méron site



## Oudon site

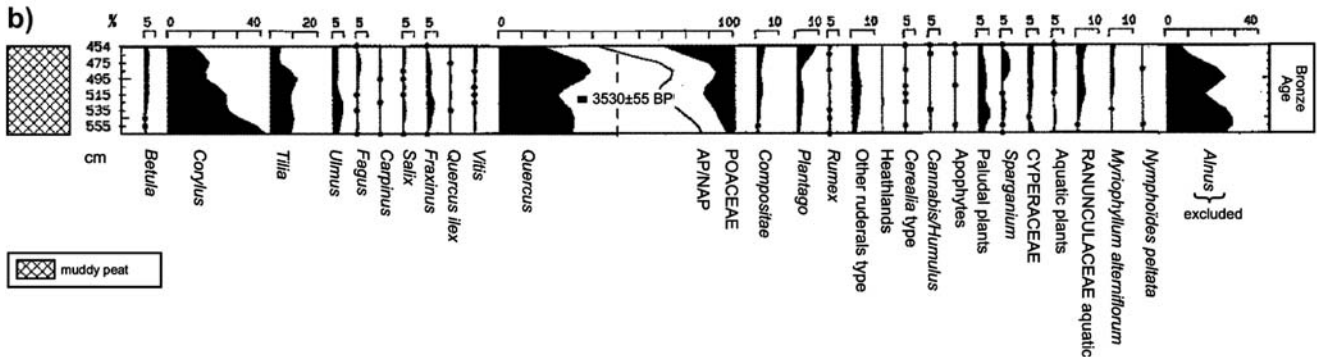


Fig. 7 The Bronze Age. Méron site (a), Oudon site (b)

variations in the height of the water column in marshlands encouraged alternating deposits of peat and silt.

### The Iron Age: 2800–2000 B.P.

There is evidence of the beginnings of the Iron Age in many places, in the continuity of agro-sylvo-pastoral practices that opened up the environment. Livestock farming predominated on the hillsides (tremendous increase in grasses and ruderal species). Crops such as cereals, vines and hemp, probably grown in the clay lowlands and well represented at Carquefou and Oudon (Fig. 8), as well as walnut, spread to plots cleared by large-scale deforestation.

During the late Celtic period, around 2350 B.P. (at Oudon) (Fig. 8b) and towards 2100 B.P. (in the Méron marsh), the entire forest system began to flourish once more, especially *Quercus* and *Corylus* woods but also *Fraxinus* (ash), *Fagus* and *Ulmus* (elm) in the Hâvre valley, at Ancenis and in the Méron marsh. This forest renewal was paralleled by a decline in the pasture and crop field system, the sites in the Loire valley seeming to have been abandoned for reasons as yet unknown.

Forest clearance began again at the end of the Iron Age, as well as livestock and crop farming with rye

(Fig. 8b) and buckwheat. Sweet chestnut, already in evidence during Neolithic times, also occurred.

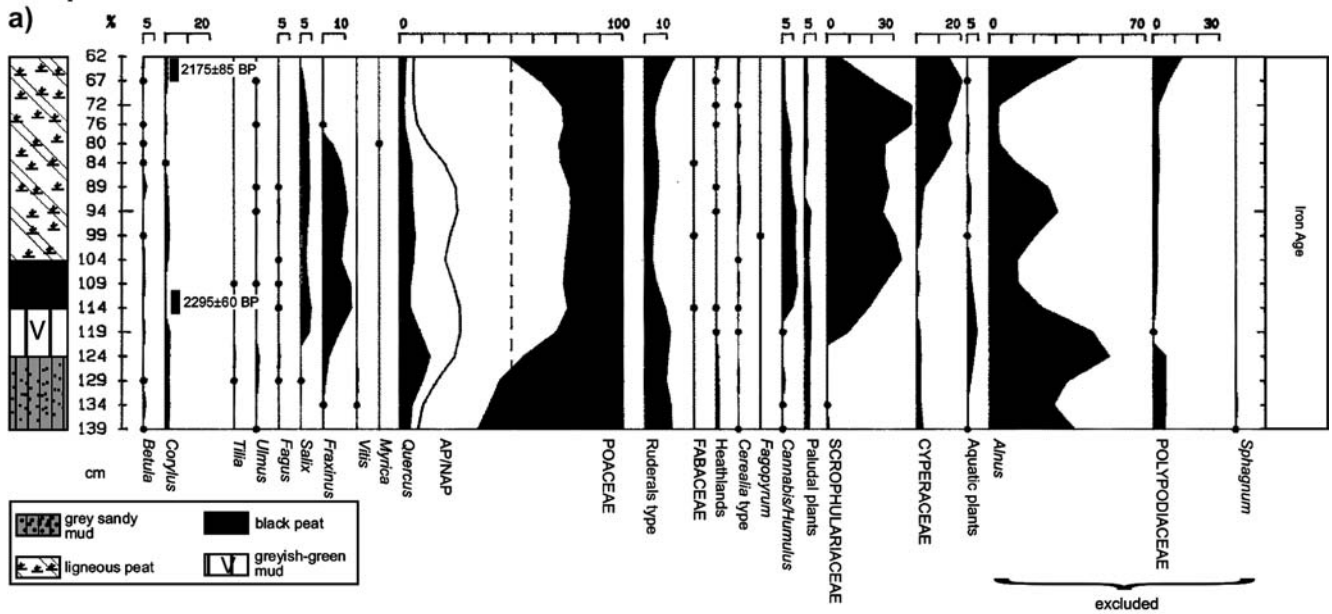
Sediment deposits in stagnant waters, mainly on clay beds, became more peaty and sandy towards the end of this period. This change may be related to a renewal of slow-moving water flows (Oudon).

### The Gallo-Roman period: 2000 B.P.–A.D. 500

As a result of the marked decline of the forest system (especially of oak woods) that began in the Bronze Age and continued in part during the Iron Age, the environment became more open than ever before (except at Cordemais where the forest cover remained), encouraging in places the growth of hazel woods (Fig. 9a), especially during the early imperial period. In Gaul *Quercus* was the most widely used timber for boat building, construction (roof timbers and foundations), tools, statuary, etc.

At the Méron site (Fig. 9b), where forests had already virtually disappeared by the beginning of the Gallo-Roman period, *Quercus* woods with *Corylus*, *Fagus* and *Betula* temporarily appeared once more, along with crop diversification. According to Barbier (1999) this development, also observed in the Mayenne area in Western France (Fig. 1), could signify the establishment of a system of forest management (which has continued until

## Carquefou fossé site



## Oudon site

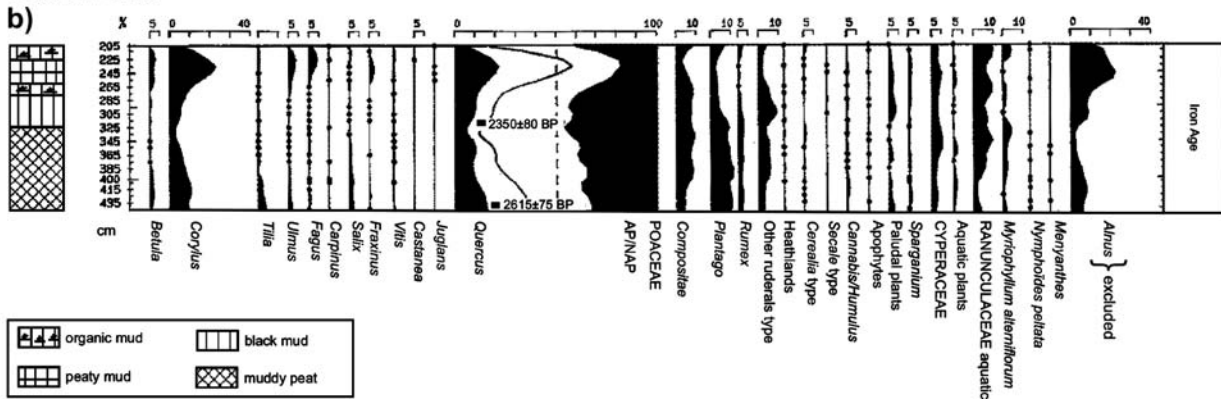


Fig. 8 The Iron Age. Carquefou fossé site (a), Oudon site (b)

the sub-present) after the intensive deforestation that occurred during the Iron Age, rather than being a sign of abandonment.

With the exception of the Munet marsh, where there is little evidence of human activity, the Gallo-Roman period is characterised by further intensification and diversification (already much in evidence during the Iron Age) of crop farming in the Armorican region (Marguerie 1992). Cereal growing, wheat and rye (Fig. 9b), clearly increased, together with apophytes. Hemp was grown in the Loire estuary around A.D. 200, as shown by Voeltzel (1987), with flax, buckwheat, walnut, sweet chestnut and vines all grown in the region. Wine growing became established in the Loire estuary (Visset 1979) near Nantes (Deschamps and Pirault 1999) and around Angers (Provost 1993) (Fig. 1).

Some marsh woodlands were intensively cleared, reflecting efforts to extend hay meadows. Pastures became

larger, livestock farming intensified and became predominant. According to Marquet and Poulain (in Provost 1993), pigs were the most common domestic animals in the Loire valley during the Gallo-Roman period.

Events during the later imperial period caused profound changes in agro-pastoral practices (Fig. 9a) that were reflected in a severe decline in crop and livestock farming and pastures. Abandoned fields reverted to woodland (especially oak). A similar situation has been shown to have developed in several Armorican peat bog areas (Marguerie 1992; Barbier 1999; Cyprien and Visset 2001) and in the Paris Basin (Leroyer 1997) and this could be the reflection of an economic and demographic decline resulting from the troubles that occurred in France in the late 3<sup>rd</sup> century A.D. (Giot 1977). Many settlements were abandoned, although in some sites that escaped the recession, Munet marshes and Cordemais for example, human activity continued to flourish.

## Vallée du Seil site

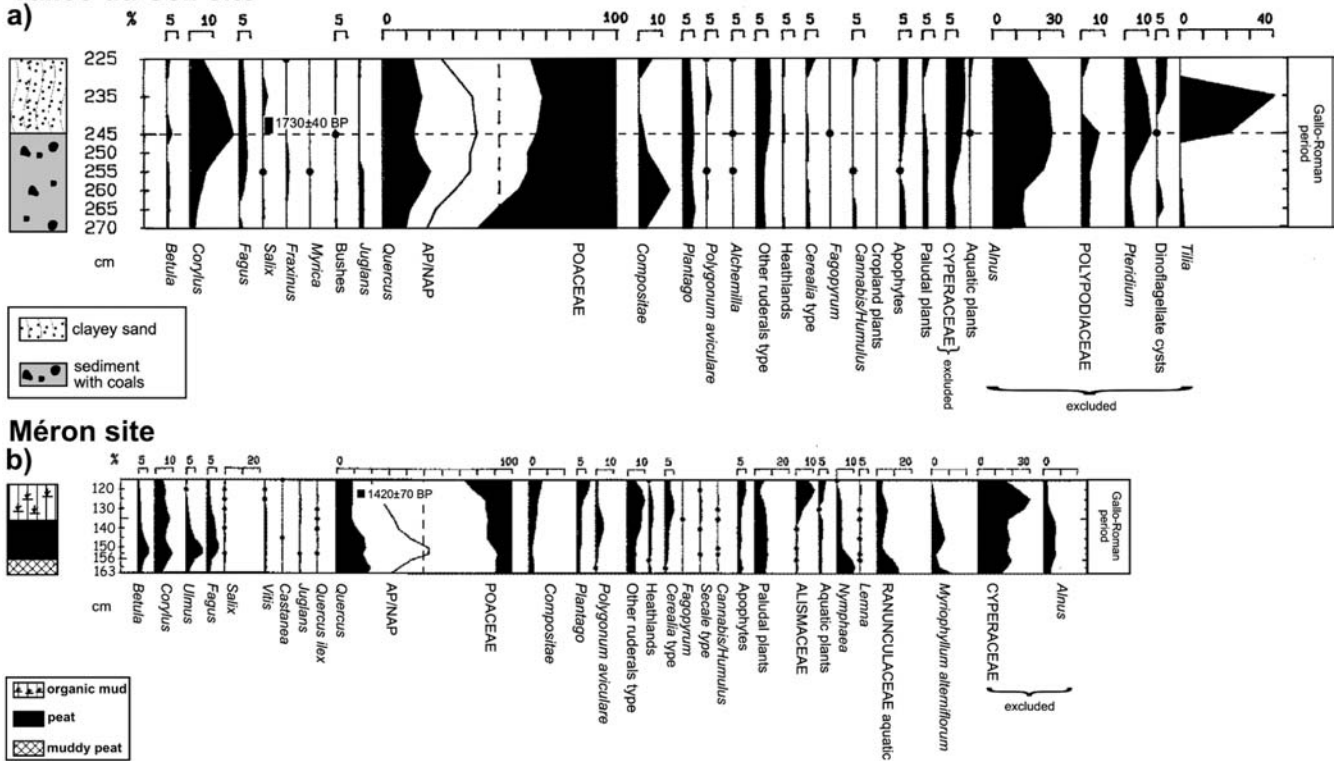


Fig. 9 The gallo-Roman period. Vallée du Seil site (a), Méron site (b)

Locally, variations in water levels resulted in changes in marshland vegetation and in deposits of mainly clay sediment.

### The Middle Ages: A.D. 500–1500

#### The Early Middle Ages

Forest clearing on hillsides began anew (Fig. 10a). Alder woods were also felled, except at the Changeon site (Fig. 1, site 9) and at Carquefou, where felling did not start until the middle of the period.

The surrounding landscape was essentially the same as during the early Gallo-Roman Empire, though with more cereal growing (except in the Munet marsh). Hemp growing flourished (Fig. 10a) although pastoral activities remained predominant. This confirms that in western France the early Middle Ages were characterised by an increase in crop and livestock farming (Barbier 1999; Ouguerram and Visset 2001a, 2001b).

#### The central Middle Ages

Except in the Munet marshes, where crop farming developed to a moderate extent, the central Middle Ages were associated everywhere with the spread of agro-sylvo-pastoralism.

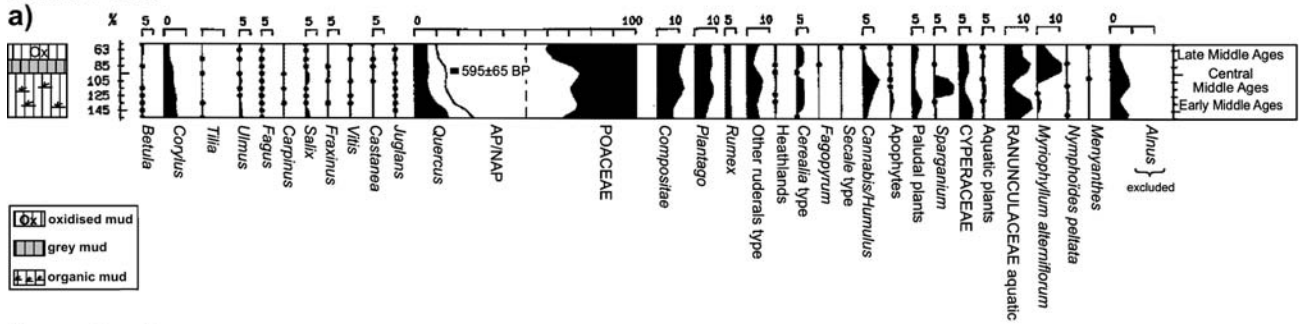
These numerous human activities resulted in a partition of local land use with hemp growing reached a peak (975 B.P.) (Fig. 10b) that reflected the activities of the textile industry along the River Loire (Carcaud et al. 2000). The open hillside landscapes prefigured the hedge-and-field systems of today.

Moreover, management of the waters of the numerous marshes began to develop as societies established water mills (Champtocé, Munet) and dams, while fisheries began to proliferate. Temporary flooding of sinks encouraged alternating peat and silt sedimentation during the entire mediaeval period. Other marshes that dried out completely during the summer were used as pasture areas for livestock herds. In the Changeon site, active hydrological phases with sand deposits were followed by very short low-activity phases with deposits of clay and peat sediments.

#### The late Middle Ages

Human encroachment on landscapes remained significant, woodlands continued to regress, livestock farming intensified along with crop farming (vine, walnut and buckwheat) although wheat seems to have declined in favour of rye. According to Ruas (1990), the Armorican region of Western France is likely to have been a rye growing area since the 10<sup>th</sup> century, and as we saw earlier, the

Oudon site



Ancenis site

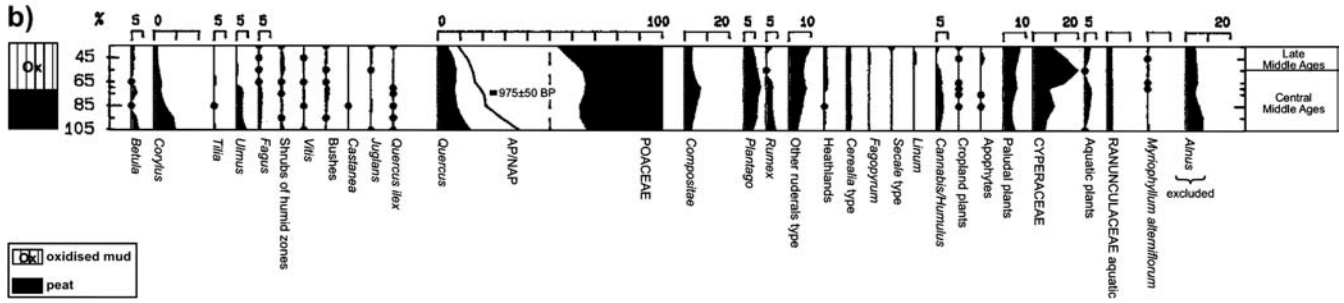
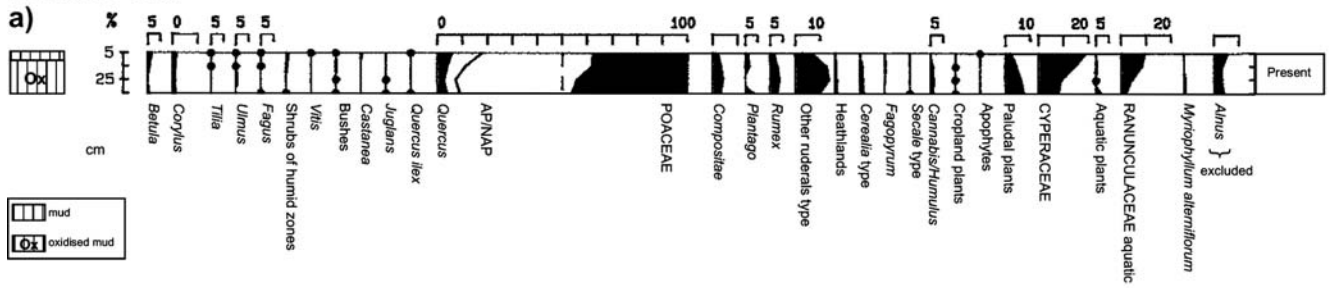


Fig. 10 The Middle Ages. Oudon site (a), Ancenis site (b)

Ancenis site



Carquefou tranchée site

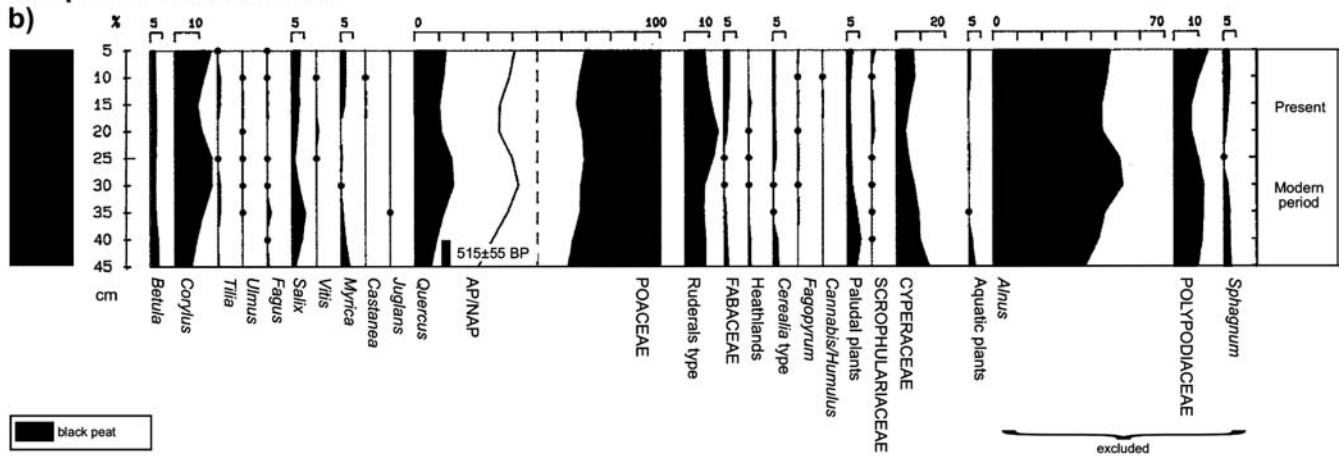


Fig. 11 The modern period and the present. Ancenis site (a), Carquefou tranchée site (b)

plant had occurred since Neolithic times in the Loire valley.

It seems that the two fibre plants, flax (Fig. 10b), also noted by Voeltzel (1987) towards A.D. 1000 and hemp, were in competition within the textile industry which had gained considerable importance in this region during the Middle Ages (Marguerie 1992).

#### *The modern period and the present: A.D. 1500 to the present*

The major characteristic of these periods is the persistence of open landscapes, although Scots pine was planted along coastlines around 1900.

Livestock farming was (and still is) the main activity along the River Loire, with numerous meadows and pasturelands extending into wetlands during the summer.

At Champocé, development activities took place before 1850, after the signing of the Drainage Acts. All uses of the marshlands influenced sedimentation patterns.

Even though no cropping practices are recorded in the Loire estuary (Cordemais), they were highly varied everywhere else. Cereals (wheat) and hemp seem to have been abandoned at Oudon and Champocé, while a hemp textile mill was established at Ancenis (Fig. 11a).

The growing of buckwheat, which continued until the 1950s at Carquefou, was extended along with legumes (Fabaceae) (Fig. 11b) in fields that were surrounded by hazel and oak hedges (Lebrun 1972).

Liming, introduced during the French Revolution, was a major technical advance that helped to improve poor soils and transform them into arable land. Lime kilns were built on calcareous outcrops.

Maize, which was known as “Italian wheat” or “Turkish wheat”, has been grown in the Loire valley near Chinon (Fig. 1) since the second half of the 18<sup>th</sup> century (Maillard 1992). It was rarely grown outside this area and only appeared in the western region of France in the 1950s.

## Conclusions

This research led to further knowledge of the evolution of the Loire river area around Cordemais, near the river mouth to Saint-Nicolas-de-Bourgueil, since the Preboreal period up to the present and takes into account its bioclimatic and subsequently its anthropic context. Human communities appear to have settled on a persistent basis in the region from the Bronze Age, although crop farming appeared as early as the middle and late Neolithic period (probably rye, buckwheat, flax and cereals) in the downstream reaches of the Loire and subsequently along the entire river. However, cereal growing was not extensive in comparison to livestock farming, which was predominant around all the sites studied. In time, crop farming intensified and became more diversified (hemp, flax, vines and later, maize) until a true system of envi-

ronmental management became established. “The environment and human societies have thus been involved in a pattern of interaction that has resulted in the construction of a landscape” (Carcaud et al. 2003).

Further research, synoptic reports and comparisons with upstream sites may help to establish the chronology of human impacts on the environment along the whole length of the Loire river. They will aid the understanding of how downstream movements of alluvial material may be linked to the destabilisation of hillsides in the Massif Central. The research is entirely in line with the studies undertaken both in the upstream reaches (Cubizolle et al. 2001; Ballut 2001) and the central part of the Loire (Garcin et al. 2001) “where the research issues are raised in an integrated way from the outset, rather than by disciplinary field” (Burnouf et al. 2001).

**Acknowledgements** We are grateful to INIST (Institut de l’Information Scientifique et Technique) for translating this paper. Technical support for this study was provided by L. Charrieau (CNRS) and G. Hauray (University of Nantes). This study is part of the national CNRS-PEVS research programme entitled ‘*Interactions Hommes/Milieus dans le bassin versant de la Loire*’ (Human/environmental interactions in the Loire river basin), which is coordinated by UMR 7041 (Archéologie et Sciences de l’Antiquité), University of Paris I, Panthéon-Sorbonne under Pr J. Burnouf.

## References

- Ballut, C. (2001). Evolution géomorphologique et hydrologique dans les marais de Limagne au cours de la seconde moitié de l’Holocène (Massif central, France). *Quaternaire*, 12, 43–51
- Barbier, D. (1999). Histoire de la végétation du nord-mayennais de la fin du Weichsélien à l’aube du XXI<sup>ème</sup> siècle. Mise en évidence d’un Tardiglaciaire armoricain. *Interactions Homme-Milieus*. Groupe d’Étude des Milieux Naturels, Nantes, vol. I, text, vol. II, illustrations
- Barbier, D., Visset, L. (1997). Logné, a peat bog of European ecological interest in the Massif armoricain, western France : bog development, vegetation and land-use history. *Vegetation History and Archaeobotany*, 6, 69–77
- Bégeot, C. (1998). Le comportement pollinique du noisetier (*Corylus avellana*), son rôle comme indicateur d’impacts anthropiques ? Exemple d’un transect dans le sud du Jura. *Acta botanica Gallica*, 145, 4, 271–277
- Behre, K.E. (1981). The interpretation of anthropogenic indicators in pollen diagrams. *Pollen et Spores*, 23, 225–245
- Behre, K.E. (1992). The history of rye cultivation in Europe. *Vegetation History and Archaeobotany*, 1, 141–156
- Bernard, J. (1996). Paléoenvironnement du Pays de Retz et du marais breton-vendéen, Thèse de Doctorat. Université de Nantes, vol I, text, vol. II, illustrations
- Burnouf, J., Carcaud, N., Cubizolle, H., Trément, F., Visset, L., Garcin, M., Serieyssel, K. (2001). Les relations sociétés/milieus physiques depuis la fin du Tardiglaciaire : les apports du programme Loire. *Quaternaire*, 12, (1–2), 5–13
- Carcaud, N., Cyprien, A.L., Visset, L. (2000). Marais et vallée de la Loire, leur mémoire des paysages depuis 10000 ans. *Archives d’Anjou, Un fleuve, des hommes: la Loire et ses affluents, une histoire tumultueuse*. numéro spécial, 4, 187–215
- Carcaud, N., Cyprien, A.L., Visset, L. (2003). Chronologie du développement des vallées et des occupations humaines dans le bassin versant central de la Loire depuis le Paléolithique moyen. Les fleuves de France atlantique, identités, espaces, représentations, mémoires. *Collection géographie et cultures, Série Etudes culturelles et régionales*, 23–40

- Cassen, S., Marchand, G., Ménanteau, L., Poissonnier, B., Cadot, R., Viau, Y. (1999). Néolithisation de la France de l'Ouest, Témoignages Villeneuve-Saint-Germain, Cerny et Chambon sur la Loire angevine et atlantique. *Gallia Préhistoire*, 41, 223–251
- Cubizolle, H., Valadas, B., Gagnaire, J., Evin, J. (2001). La dynamique des versants dans le bassin de la Dore durant la deuxième moitié de l'Holocène (Massif central, France): Premières données géoarchéologiques et datations radiocarbones. *Quaternaire*, 12, 15–29
- Cyprien, A.L. (2002). Chronologie de l'interaction de l'homme et du milieu dans l'espace central et aval de la Loire (Ouest de la France). Groupe d'Étude des Milieux Naturels, Nantes, vol I text, vol II illustrations
- Cyprien, A.L., Carcaud, N., Visset, L. (2001). Etude paléoenvironnementale du marais de Distré (Saumurois): géoarchéologie d'une zone humide depuis le Préboréal. *Quaternaire*, 12, 89–101
- Cyprien, A.L., Visset, L. (2001). Paleoenvironmental study of the Carquefou site (Massif Armoricaire, France) from the end of the Subboreal. *Vegetation History and Archaeobotany*, 10, 139–149
- Deschamps, S., Pirault, L. (1999). Rezé, cité des Pictons. *Archeologia*, 353, 34–45
- Dupont, P. (2001). Atlas floristique de la Loire-Atlantique et de la Vendée, état et avenir d'un patrimoine. Société des Sciences Naturelles de l'Ouest de la France, 2 vols
- Fournier, P. (1946). Les quatre flores de la France, édition Paul Lechevalier, Paris
- Galop, D. (1998). La forêt, l'homme et le troupeau dans les Pyrénées - 6000 ans d'histoire de l'environnement entre Garonne et Méditerranée. Geode—Laboratoire d'écologie terrestre, 285 p.
- Garcin, M., Farjanel, G., Giot, D. (2001). Eléments radiochronologiques et palynologiques sur les alluvions du lit majeur de la Loire (Val d'Avaray, Loir-et-Cher, France). *Quaternaire*, 12, 69–88
- Giot, P.R. (1977). Un aspect méconnu du déclin du Bas Empire. *Bulletin des Sociétés Archéologiques du Finistère*, 105, 97–98
- Girard, M. (1973). Pollens et Paléolithologie. L'Homme, hier et aujourd'hui. In: recueil d'études en hommage à André Leroi-Gourhan. Edition Cujas, Paris, 317–332
- Gruet, M. (1978). Le dolmen immergé de la boire de Champocé (Maine et Loire). *Bulletin de la Société Préhistorique Française*, 75, 24–28
- Lebrun, F. (1972). Histoire des pays de la Loire, Orléanais, Touraine, Anjou, Maine
- Leroyer, C. (1997). Homme, climat, végétation au tardi- et post-glaciaire dans le bassin parisien: apports de l'étude palynologique des fonds de vallées. Thèse de Doctorat, Université de Paris I, 2 vols
- Maillard, B. (1992). Les campagnes de Touraine au XVIII<sup>ème</sup> siècle. Etude d'histoire économique et sociale. Thèse d'Etat, Université de Rennes II, 5 vols
- Marambat, L. (1995). Paysages de la façade atlantique girondine et de la saintonge au post-glaciaire. L'empreinte de l'homme. CNRS Editions, Cahiers du Quaternaire, 21, 177 p.
- 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, 313 p.
- Ménanteau, L. (1973). Le lit de la Loire entre Saint-Florent-le-Vieil et Champocéaux: essai de géomorphologie holocène. Mémoire de Maîtrise de Géographie, Université de Nantes, 3 vols
- Morzadec-Kerfourn, M.T. (1974). Variations de la ligne de rivage armoricaine au Quaternaire. Mémoire des Sociétés Géologiques et minéralogiques de Bretagne, 17, Rennes
- Morzadec-Kerfourn, M.T. (1976). La signification écologique des dinoflagellés et leur intérêt pour l'étude des variations du niveau marin. *Revue de Micropaléontologie*, 18, 229–235
- Morzadec-Kerfourn, M.T. (1992). Upper Pleistocene and Holocene Dinoflagellate cyst assemblages in marine environments of the Mediterranean sea and the Northwest Atlantic coast of France. In: Head, D. and Wrenn, J.H. (eds) Neogene and Quaternary dinoflagellate cysts and acritarchs. American Association of Stratigraphic Palynologists Foundation. Dallas, pp. 121–132
- Nassiet, M. (1998). La diffusion du blé noir en France à l'époque moderne. *Histoire et Sociétés Rurales*, 9, 57–76
- Ouguerram, A. (2002). Etude palynologique de la vallée de l'Erdre (affluent de la Loire, Massif armoricain, France) de la fin du tardiglaciaire aux époques actuelles. Mise en évidence de la pénétration marine flandrienne. Interactions Sociétés/Végétation. Thèse de Doctorat d'Etat en Biologie, Université Moulay Ismail (Maroc) et Nantes, 2 vols
- Ouguerram, A., Visset, L. (2001a). Paysages et interactions homme/milieu dans la moyenne vallée de l'Erdre du Néolithique aux Epoque actuelles, étude pollinique du marais de Lisle. *Annales de Bretagne et des Pays de l'Ouest Anjou, Maine, Touraine*, 108, 129–146
- Ouguerram, A., Visset, L. (2001b). Palynologie de la tourbière de Nay dans la vallée de l'Erdre, affluent de la Loire (Massif armoricain, France): histoire de la végétation et du peuplement humain. *Journal Botanique de la Société botanique de France*, 13, 35–45
- Pirazzoli, P.A. (1991). World atlas of Holocene sea-level changes. Elsevier Oceanography series, 58, 69–82
- Planchais, N. (1967). Analyse pollinique de la tourbière de Gizeux (Indre-et-Loire) et étude du chêne vert à l'optimum climatique. *Pollen et Spores*, 9, 505–520
- Prigent, D., Visset, L., Morzadec-Kerfourn, M.T., Lautrido, J.P. (1983). Human occupation of the submerged coast of the Massif Armoricaire and postglacial sea level changes. In: Symposium Proceedings of La Jolla (Californie). Quaternary coastlines. Academic press, 303–324
- Provost, M. (1993). Le val de Loire dans l'Antiquité. Supplément à Gallia, Paris, CNRS, 52, 425 p.
- Puertas, O. (1997). Evolution de la végétation depuis le Dryas récent dans la plaine alluviale de Montpellier (Hérault, France) à partir de l'analyse pollinique. Dynamique naturelle et anthropisation du milieu. Thèse de Doctorat, Université de Franche-Comté
- Ruas, M.P. (1990). Recherches carpologiques dans le massif armoricain du mésolithique au Bas Moyen Age. Diplôme d'Etudes Approfondies en Histoire et Civilisations, EHESS, Paris, inédit, 93 p.
- Shennan, I. (1986). Flandrian sea-level changes in Fenland II: tendencies of sea-level movement altitudinal changes and local and regional factors. *Journal of Quaternary Science*, 1, 155–179
- Stuiver, M., Reimer, P.J. (1998). *Radiocarbon*, 40, 1041–1083
- Trément, F. (1999). Archéologie d'un paysage. Les étangs de Saint-Blaise (Bouches-du-Rhône). Documents d'Archéologie 0). Française n°74, Editions de la Maison des Sciences de l'Homme. Paris, 314 p.
- Visset, L. (1979). Recherches palynologiques sur la végétation pléistocène et holocène de quelques sites du district phytogéographique de Basse-Loire. *Bulletin de la Société des Sciences Naturelles de l'Ouest de la France*, supplément hors série, Nantes, 282 p.
- Visset, L. (1980). Etude palynologique de l'abri sous roche de Roc-en-Pail a Chalonnes-sur-Loire (Maine-et-Loire). Mémoire n°4 Société des Etudes Scientifiques en Anjou, 87–117
- Visset, L. (1988). The Brière Marshlands : a palynological survey. *New Phytologist*, 110, 409–424
- Visset, L., Hauray, G. (1980). Palynologie : une technique de sondage pour les sédiments meubles. *Bulletin de la Société des Sciences Naturelles de l'Ouest de la France*, nouvelle série, 2, 129–138
- Visset, L., Hauray, G. (1988). The mechanized " Gik " corer: seven years of news and improvement. *Boréas*, 17, 329–331
- Visset, L., Girarclos, O., Lambert, G.N. (1994). La forêt de chênes sur tourbe à l'Ile d'Errand dans les marais de Brière (Massif armoricain, France). Palynologie et premiers résultats dendrochronologiques. *Quaternaire*, 5, 69–77
- Visset, L., Sellier, D., L'Helgouac'h, J. (1995). Le paléoenvironnement de la région de Carnac. Sondage dans le marais de

- Kerdual, La Trinité-sur-Mer (Morbihan). *Revue Archéologique de l'Ouest*, 12, 57–71
- Visset, L., L'Helgouac'h, J., Bernard, J. (1996). La tourbière submergée de la pointe de Kerpenhir à Locmariaquer (Morbihan). Étude environnementale et mise en évidence de déforestations et de pratiques agricoles néolithiques. *Revue Archéologique de l'Ouest*, 13, 79–87
- Visset, L., Pont, C., Carcaud, N., Bernard, J., Violot, J.M. (1999). Étude paléoenvironnementale de la vallée du Lane du Néolithique au Moyen Age, Saint Nicolas de Bourgueil (Indre et Loire), La prairie du Cassoir. *Quaternaire*, 10, 247–261
- Visset, L., Cyprien, A.L., Carcaud, N., Ouguerram, A., Barbier, D., Bernard, J. (2002). Les prémices d'une agriculture diversifiée à la fin du Mésolithique dans le Val de Loire (Loire armoricaine, France). *Comptes Rendus Palevol*, 1, 51–58
- Voeltzel, D. (1987). Recherches pollenanalytiques sur la végétation holocène de la plaine alluviale de l'estuaire de la Loire et des coteaux environnants. Thèse de doctorat, Université Aix-Marseille III, 175 p.
- Zeist, W. van (1963). Recherches palynologiques en Bretagne occidentale. *Norwis*, 10, 37, 5–19